Journal of CHEMICAL EDUCATION

OFFICIAL PUBLICATION OF THE DIVISION OF CHEMICAL EDUCATION OF THE AMERICAN CHEMICAL SOCIETY

R. D. Reed, *Chairman* N. D. Cheronis, *Vice Chairman* P. H. Fall, *Secretary* Virginia Bartow, *Treasurer*

VOL. 18 JUNE, 1941 NO. 6

NORRIS W. RAKESTRAW
Editor

Marilyn L. Evans *Asst. to the Editor*
Harvey F. Mack *Business Manager*
Cyrus S. Fleck *Asst. Business Manager*
B. F. Gould *Advertising Manager*
C. L. Wells *Circulation Manager*

BOARD OF PUBLICATION

Ross A. Baker, *Chairman*

S. R. Brinkley P. H. Fall
N. D. Cheronis R. D. Reed

ASSOCIATE EDITORS

Hubert N. Alyea
Princeton University
Aubison T. Burtsell
College of the City of New York
Tenney L. Davis
Mass. Institute of Technology
Ed. F. Degering
Purdue University
William A. Felsing
University of Texas
Malcolm M. Haring
University of Maryland
Philip A. Leighton
Stanford University
Laurence L. Quill
Ohio State University
Elbert C. Weaver
Bulkeley High School
Hartford, Conn.

BUSINESS & PUBLICATION OFFICES
20th and Northampton Streets
Easton, Pennsylvania

EDITORIAL OFFICE
Metcalf Chemical Laboratory
Brown University, Providence, R. I.

ADVERTISING OFFICE
11 West 42nd Street
New York, N. Y.

Frontispiece—Frederick George Donnan XV
Editor's Outlook 251
What's Been Going On 252
Bunsen's Trip to Iceland as Recounted in Letters to his Mother, *Ralph E. Oesper and Karl Freudenberg* 253
In Retrospect 260
An Electrical Precipitator for Research and Demonstration Purposes, *John H. Billman and R. Vincent Cash* 261
The Second Law of Thermodynamics, *R. H. Wright* 263
Some Lecture Experiments Using Rubber Balloons, *Edwin T. Mitchell* 269
Capillary Pipets, *H. A. Frediani and L. Gamble* 270
Mixed Indicators in the Elementary Quantitative Analysis Course, *W. S. McGuire* 271
Effect of Concentration on Reaction Rate and Equilibrium, *Arthur A. Frost* 272
Recent Advances in the Chemistry of the Proteins, *Dwight C. Carpenter* 274
A History of the Match Industry, *M. F. Crass, Jr.* 277
Frederick George Donnan (Biographical Sketch), *Ralph E. Oesper* 282
The Geometric Interpretation of the Method of Intercepts, *H. S. van Klooster* .. 283
The Problem of Physical Chemistry for Chemical Engineers, *J. C. Elgin* 284
Summer Change of Address 285
Structural Precipitates: The Silicate Garden Type, *Thomas H. Hazlehurst* 286
Students and the Selective Service Regulations 289
A Scientific Catechism of 1870 290
The Alternations in Stability of Compounds of the Elements of Group V, *J. H. Hildebrand* 291
An Ammonium Chloride "Chimney," *Harry L. Davis and J. W. Neckers* 292
High-School Chemistry
Project Teaching in High-School Chemistry, I. Exhibits and Posters, *William C. Curtis* 293
Supplementary Experiments in High-School Chemistry 295
Letters 296
Out of the Editor's Basket 298
Third Summer Conference of the N.E.A.C.T. 299
Recent Books 300
Trade Announcements XVIII

Subscription Price: $3.00 per year; Canada $3.50; other countries $4.00. Issued monthly. Single copies of issues in current year, 50c each; all other single copies, one dollar. Foreign remittances must be accompanied by International Money Order.
No claims for copies of journals lost in the mails can be allowed unless such claims are received within sixty (60) days of the date of issue and no claims can be allowed for issues lost as a result of insufficient notice of change of address.
Manuscript for publication should be directed to the editor. Prospective authors are urged to avoid diffuse writing and to observe the forms outlined in our Notice to Authors of Papers as it appears on page XX of the April, 1941, issue.
Entered as second-class matter, January 31, 1924, at the Post Office at Easton, Pa., under the act of March 3, 1879. Accepted for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized January 31, 1924.
The JOURNAL OF CHEMICAL EDUCATION *is indexed in the Education Index, Industrial Arts Index, and, in part, in the Quarterly Cumulative Index Medicus*

COPYRIGHT, 1941, BY DIVISION OF CHEMICAL EDUCATION, AMERICAN CHEMICAL SOCIETY

BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS
LIBRARY

SEMI-MICRO REAGENT BOTTLES

WITH CHEMICAL SYMBOLS FUSED IN WITH CERAMIC GLASS

Available in an assortment of eighty-nine labels selected to meet the requirements of the most widely used text books of semi-micro methods

2284-A. **2284-C.** **2284-F.** **2284-H.** **2284-K.** **2284-M.**

BOTTLES, REAGENT, Semi-Micro, developed at the suggestion of E. L. Haenisch of the Department of Chemistry, Villanova College, especially for use in semi-micro qualitative analysis. With chemical symbols fused in with ceramic glass, either white or black as may provide greater visibility against the reagent for which the bottle is intended.

The labels listed below have been selected to meet both individual student and shelf requirements of several widely used text books of semi-micro micro methods, i.e.:

Hogness and Johnson, *"Qualitative Analysis and Chemical Equilibrium,"* (Henry Holt & Co., New York, N. Y., 1940).

Meldrum, Flosdorf and Daggett, *"Semimicro Qualitative Analysis of Inorganic Materials,"* (American Book Co., New York, N. Y., 1939).

Arthur and Smith, *"Semi-Micro Qualitative Analysis,"* (McGraw-Hill Book Co., New York, N. Y., 1938).

Belcher and Williams, *"A Course in Qualitative Analysis based on Macro and Semi-Micro Methods,"* (Houghton Mifflin Co., Boston, Mass., 1938).

Middleton and Willard, *"Semimicro Qualitative Analysis,"* (Prentice-Hall, Inc., New York, N. Y., 1939).

Kelsey and Dietrich, *"Fundamentals of Semimicro Qualitative Analysis,"* (The Macmillan Co., New York, N. Y., 1940).

Evans, Garrett and Quill, *"Semimicro Qualitative Analysis,"* (Ginn and Co., Boston, Mass., 1940).

2284-A. Bottles, Reagent, Semi-Micro, for liquids, 1/2 oz. capacity, as above described, consisting of a square, flint glass bottle, machine made, narrow mouth, with neck finished with standard, continuous screw thread. Complete with black plastic cap with glass dropper and rubber bulb with flange which serves as cap liner. With symbols only in white, fused-in lettering. **Each** ..... .20

Number	Symbol	Number	Symbol	Number	Symbol
100.	Aluminon	190.	CCl_4	280.	KNO_3
105.	NH_4Ac	195.	Bi Reag.	285.	$KMnO_4$
110.	$(NH_4)_2CO_3$	200.	DiMe Glyox	290.	KSCN
115.	NH_4Cl	205.	$FeCl_3$	295.	Sb Reag.
120.	NH_4I	210.	$Fe(NO_3)_3$	300.	AgAc
125.	Amm. Moly.	215.	$FeSO_4$	305.	$AgNO_3$
130.	NH_4NO_3	220.	H_2O_2	310.	NaAc
135.	$(NH_4)_2C_2O_4$	225.	$PbAc_2$	315.	Na_2CO_3
140.	$(NH_4)_2Sx$	230.	$Pb(NO_3)_2$	320.	$Na_3Co(NO_2)_6$
145.	$(NH_4)_2SO_4$	235.	Mag Mix	325.	$NaNO_2$
150.	NH_4SCN	240.	$HgCl_2$	330.	NaH_2PO_4
155.	$BaAc_2$	245.	CH_3OH	335.	Na_2HPO_4
160.	$BaCl_2$	250.	K Reag.	340.	$NaHSO_4$
165.	$Ba(OH)_2$	255.	S&O (Mg)	345.	Na_2SO_4
170.	Cu Reag.	260.	Co Reag.	350.	$SnCl_2$
175.	Sn Reag.	265.	K_2CrO_4	355.	$Zn(NO_3)_2$
180.	$CaAc_2$	270.	KCN	360.	Na Reag.
185.	$CaCl_2$	275.	$K_4Fe(CN)_6$	365.	$ZrOCl_2$

2284-C. Bottles, Reagent, Semi-Micro, for liquids, 1/2 oz. capacity; similar to 2284-A, i.e. a square, flint glass bottle, machine made, narrow mouth, but with glass dropping pipette ground into the neck to form a stopper. Complete with rubber bulb and with symbols only in white fused-in lettering. **Each** ..... .70

Number	Symbol	Name
400.	$Br_2.Aq$	Bromine Water
410.	$MnCl_2$	Manganous Chloride

2284-F. Bottles, Reagent, Semi-Micro, for acids and bases, 1 oz. capacity; identical with 2284-A but of larger capacity, i.e. consisting of square, flint glass bottle complete with black plastic cap with glass dropper and rubber bulb. With symbols only in white, fused-in lettering. **Each** ..... .21

Number	Symbol	Number	Symbol	Number	Symbol
500.	HAc 6M	515.	HCl 6M	530.	NaOH 6M
505.	NH_3 6M	520.	HCl 3M	535.	H_2SO_4 6M
510.	NH_3 3M	525.	HNO_3 6M		

2284-H. Bottles, Reagent, Semi-Micro, for acids and bases, 1 oz. capacity; similar to 2284-F, i.e. a square, flint glass bottle, machine made, narrow mouth, but with glass dropping pipette ground into the neck to form a stopper. Complete with rubber bulb and with symbols only in white, fused-in lettering. **Each** ..... .72

Number	Symbol	Number	Symbol
550.	NH_3 conc.	560.	HNO_3 conc.
555.	HCl conc.	565.	H_2SO_4 conc.

2284-K. Bottles, Reagent, Semi-Micro, for solids, 1/2 oz. capacity, as above described, consisting of a square, flint glass bottle, machine made, narrow mouth, complete with black plastic screw cap with plastic liner. With symbols only in white, fused-in lettering. **Each** ..... .17

Number	Symbol	Number	Symbol	Number	Symbol
575.	Al	595.	$K_3Fe(CN)_6$	610.	$Na_3Co(NO_2)_6$
580.	$FeSO_4$	600.	$KMnO_4$	615.	Na_2O_2
585.	Fe	605.	$NaBiO_3$	620.	Zn
590.	Mg				

2284-M. Bottles, Reagent, Semi-Micro, for solids, 1/2 oz. capacity, identical with 2284-K but with symbols in black, fused-in lettering. **Each** ..... .17

Number	Symbol	Number	Symbol	Number	Symbol
650.	NH_4Cl	670.	$CaCO_3$	690.	KNO_2
655.	NH_4NO_3	675.	CaF_2	695.	Na_2CO_3
660.	$(NH_4)_2SO_4$	680.	K_2CO_3	700.	$Na_2S_2O_3$
665.	Borax	685.	$KClO_3$		

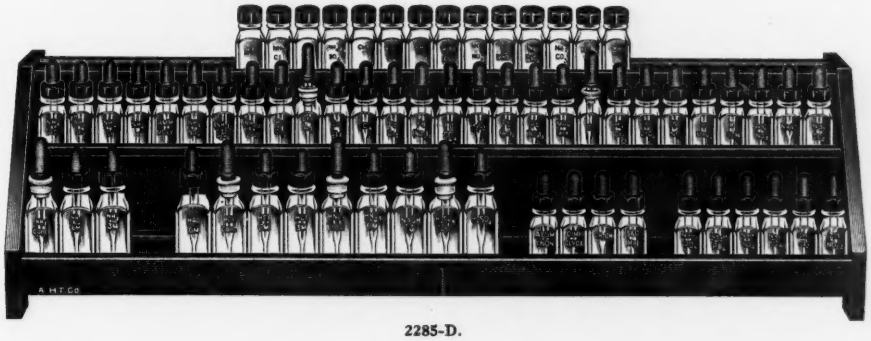
10% discount in carton containing 1 dozen, one label and catalogue number only

25% discount in lots of 1/2 gross } 2284-A to 2284-M, incl., assorted in cartons of
40% " " " " 1 " } 1 dozen of each label

ARTHUR H. THOMAS COMPANY, PHILADELPHIA, PA., U.S.A.

SEMI-MICRO REAGENT BOTTLES

Set of selected Reagent Bottles complete in acid-resistant Rack, for use in Hogness and Johnson semi-micro methods



2285-D.

2285. Rack for Semi-Micro Reagent Bottles, as suggested by E. L. Haenisch, of Villanova College. Of hardwood with acid-resistant dull black finish for convenience in reading labels; 28 inches long × $5^3/_4$ inches wide × $7^1/_4$ inches total height. Bottom row accommodates twelve 1-oz. bottles $1^3/_{16}$ inches square and twelve $^1/_2$-oz. bottles $^{15}/_{16}$-inch square; second and top rows each accommodate twenty-eight $^1/_2$-oz. bottles of the same size; or a total of sixty-eight $^1/_2$-oz. bottles and twelve 1-oz. bottles. Labels are in full view at all times as the square bottles can not be turned in the rack. These racks are offered as a convenience for laboratories where shop facilities for making such racks are not readily available..... **6.50**

SET OF SEMI-MICRO REAGENT BOTTLES IN RACK, for student use in qualitative micro analysis in conjunction with Hogness and Johnson, *"Qualitative Analysis and Chemical Equilibrium,"* (Henry Holt & Co., New York, N. Y., 1940). Consisting of 2285 Rack and the following assortment of sixty-four labeled bottles, i.e., fifty-two $^1/_2$-oz. bottles and twelve 1-oz. bottles:

For Liquids

Cat. No.	Label. No.	Name	Label
2284-A	105	Ammonium Acetate	NH_4Ac
"	110	Ammonium Carbonate	$(NH_4)_2CO_3$
"	115	Ammonium Chloride	NH_4Cl
"	120	Ammonium Iodide	NH_4I
"	125	Ammonium Molybdate	Amm. Moly.
"	130	Ammonium Nitrate	NH_4NO_3
"	135	Ammonium Oxalate	$(NH_4)_2C_2O_4$
"	145	Ammonium Sulfate	$(NH_4)_2SO_4$
"	160	Barium Chloride	$BaCl_2$
2284-C	400	Bromine Water	Br_2.Aq
2284-A	185	Calcium Chloride	$CaCl_2$
"	190	Carbon Tetrachloride	CCl_4
"	205	Ferric Chloride	$FeCl_3$
"	210	Ferric Nitrate	$Fe(NO_3)_3$
"	215	Ferrous Sulfate	$FeSO_4$
"	220	Hydrogen Peroxide	H_2O_2
"	225	Lead Acetate	$PbAc_2$
"	230	Lead Nitrate	$Pb(NO_3)_2$
"	235	Magnesia Mixture	Mag Mix
2284-C	410	Manganous Chloride	$MnCl_2$
2284-A	240	Mercuric Chloride	$HgCl_2$
"	265	Potassium Chromate	K_2CrO_4
"	280	Potassium Nitrite	KNO_2
"	285	Potassium Permanganate	$KMnO_4$
"	290	Potassium Thiocyanate	KSCN
"	305	Silver Nitrate	$AgNO_3$
"	310	Sodium Acetate	NaAc
"	315	Sodium Carbonate	Na_2CO_3
"	330	Primary Sodium Phosphate	NaH_2PO_4
"	335	Secondary Sodium Phosphate	Na_2HPO_4
"	340	Sodium Bisulfate	$NaHSO_4$
"	345	Sodium Sulfate	Na_2SO_4
"	350	Stannous Chloride	$SnCl_2$
"	355	Zinc Nitrate	$Zn(NO_3)_2$

For Selected Organics

Cat. No.	Label No.	Name	Label
2284-A	100	Aluminon (Al reagent)	Aluminon
"	200	Dimethylglyoxime (Ni reagent)	DiMe Glyox
"	245	Methyl Alcohol	CH_3OH
"	255	*p*-Nitrobenzeneazoresorcinol (Mg reagent)	S&O (Mg)

For Acids and Bases

2284-F	500	Acetic Acid, glacial, 6M	HAc 6M
2284-H	550	Ammonium Hydroxide, conc., 15M	NH_3 conc.
2284-F	505	Ammonium Hydroxide, 6M	NH_3 6M
"	510	Ammonium Hydroxide, 3M	NH_3 3M
2284-H	555	Hydrochloric Acid, conc., 12M	HCl conc.
2284-F	515	Hydrochloric Acid, 6M	HCl 6M
"	520	Hydrochloric Acid, 3M	HCl 3M
2284-H	560	Nitric Acid, conc., 16M	HNO_3 conc.
2284-F	525	Nitric Acid, 6M	HNO_3 6M
"	530	Sodium Hydroxide, 6M	NaOH 6M
2284-H	565	Sulfuric Acid, conc., 18M	H_2SO_4 conc.
2284-F	535	Sulfuric Acid, 6M	H_2SO_4 6M

For Solids

2284-K	575	Aluminum	Al
2284-M	650	Ammonium Chloride	NH_4Cl
"	655	Ammonium Nitrate	NH_4NO_3
"	660	Ammonium Sulfate	$(NH_4)_2SO_4$
"	675	Calcium Fluoride	CaF_2
2284-K	580	Ferrous Sulfate	$FeSO_4$
"	585	Iron	Fe
"	595	Potassium Ferricyanide	$K_3Fe(CN)_6$
2284-M	690	Potassium Nitrite	KNO_2
2284-K	600	Potassium Permanganate	$KMnO_4$
"	605	Sodium Bismuthate	$NaBiO_3$
2284-M	695	Sodium Carbonate	Na_2CO_3
"	700	Sodium Thiosulfate	$Na_2S_2O_3$
2284-K	620	Zinc	Zn

2285-D. Set of Semi-Micro Reagent Bottles in Rack, as above described, complete with 2285 Rack and assortment of sixty-four labeled bottles as itemized above, but without reagents..... **22.00**

Prices subject to change without notice

ARTHUR. H. THOMAS COMPANY

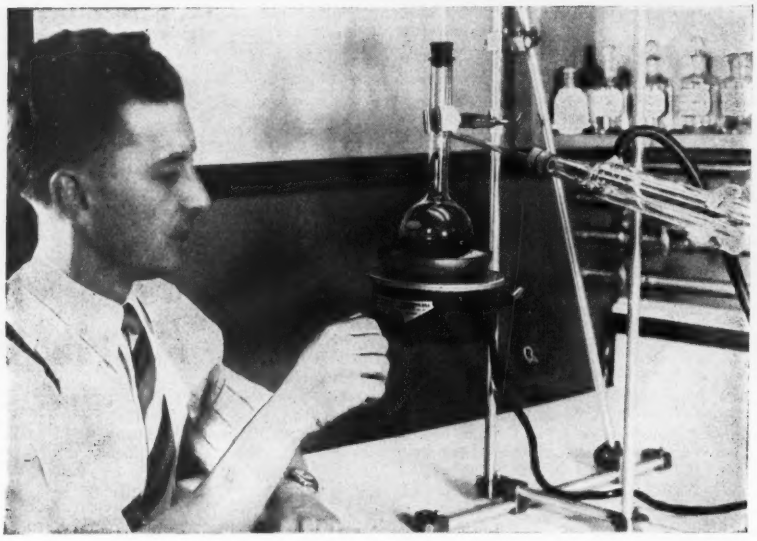
RETAIL—WHOLESALE—EXPORT

LABORATORY APPARATUS AND REAGENTS

WEST WASHINGTON SQUARE, PHILADELPHIA, U. S. A.

Cable Address, "Balance," Philadelphia

THE APPROVED LABORATORY HEATING APPLIANCES FOR *Gas* OR *Electricity*



The New Autemp Heater
An inexpensive, thermostatically-controlled hot plate.

These efficient heating appliances were designed in Fisher's Development Laboratory and are manufactured in Fisher's Instrument Shops.

They are made especially to meet the requirements of laboratory work and are a great convenience in the educational laboratory.

Fisher AUTEMP Heater

FOR *Electricity* This is a sturdy heating device of adequate size and capacity for a large number of laboratory heating operations. The 6-inch cast aluminum heating surface, the one-piece aluminum body, the heavy heating element, the efficient thermostat and the integral clamping arm were designed and built for utility, convenience, and enduring service.

The temperature of a liquid in a beaker on this heater can be maintained automatically at any point from 95° to 256°C. by adjusting the thermostat.

The Fisher Autemp Heater (*Trade Name Registered*) uses current only when the thermostat turns it on and then the consumption is only 450 watts. Thus, it is economical to operate. These advantages, together with its low price, recommend it as a general multi-purpose heater for many uses in every laboratory. (*State whether for use with 110 volt or 220 volt A.C.*)

Fisher Autemp Heater.....$6.00

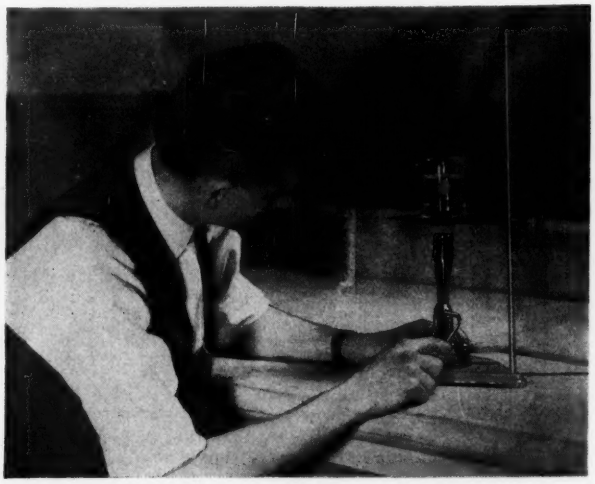
Fisher Burner

FOR *Gas* The Fisher Burner produces an intensely hot flame for all types of laboratory heating operations including many ignitions and incinerations which otherwise would require the use of compressed air.

The flame produced by the Fisher Burner differs from that of the Bunsen burner in nearly every respect. Instead of the cold cone and hot tip characteristic of the Bunsen flame, the Fisher flame is short and wide and is uniformly hot throughout. The entire Fisher flame is 2,300°F. hotter than the inner cone of the Bunsen flame. This is made possible by the unique design, the shape and size of the air-gas mixing chamber, the injector-shaped tube, and the deep grid on the top.

The Fisher Burner is constructed of non-rusting materials throughout. The base is a one-piece white metal casting. The needle-valve for regulating the gas has a packing gland which prevents leaks. The diameter of the grid of this burner is 42 mm. It burns either natural or artificial gas efficiently.

No. 3-902 Fisher Burner, with 42 mm. grid, $2.00



The Fisher High-Temperature Burner
It saves 37% in gas and 25% in time in performing laboratory heating operations.

Manufactured and Distributed by

FISHER SCIENTIFIC CO.
711-723 Forbes Street • Pittsburgh, Penna.

EIMER AND AMEND
205-223 Third Avenue • New York, N. Y.

Headquarters for Laboratory Supplies

Congress, under a Joint Resolution
of July 27, 1866, provided that each
of the states be furnished with a
complete set of weights, running
from 10 kilograms to 1 milligram
. . . unvarying standards of weight
throughout the states.

Unvarying Standards

Equally as unvarying is the conformity of Mallinckrodt A. R. Chemicals to their predetermined standards of purity. Where absolute accuracy in analytical work is essential, Mallinckrodt reagents insure the purity that facilitates precision in the laboratory.

Send for new catalogue of Mallinckrodt Analytical Reagents and other chemicals for laboratory use. Contains detailed descriptions of chemicals for every type of analytical work . . . gravimetric, gasometric, colorimetric or titrimetric.

FINE CHEMICALS
Mallinckrodt
SINCE 1867

MALLINCKRODT CHEMICAL WORKS

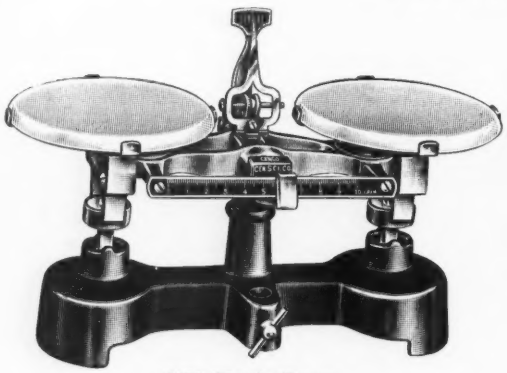
ST. LOUIS • PHILADELPHIA • MONTREAL

CHICAGO • NEW YORK • TORONTO

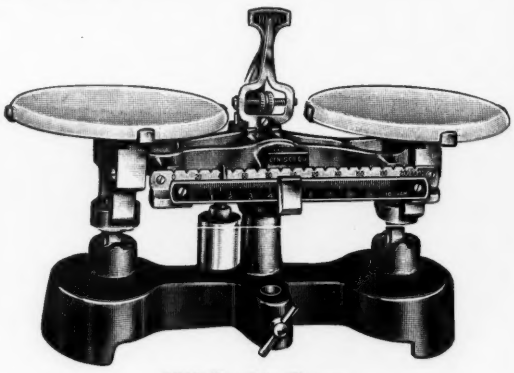
Chemical Laboratory and Industrial Batch

TRIP SCALE BALANCES

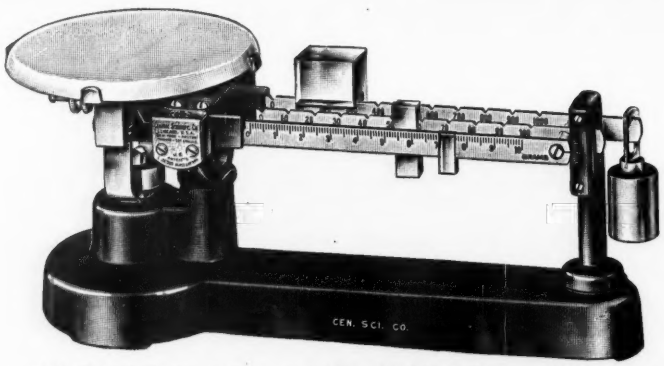
AGATE BEARING



3470 Single Beam



3560 Double Beam



3620 Triple Beam shown with No. 3622 Attachment Weight.

In every specification the Cenco Trip Scales are the most serviceable balances that could possibly be made . . . sturdy—durable—sensitive—accurate.

Strength and durability are secured from the choice of the materials of construction and the design of the parts . . . cast alloy beams and pan hangers—nickel-silver rider scales, index scales and pointers—cast iron bases finished in baked black japan. The pans are of vitrolite. The whole combination is one of pleasing design and being made of non-corrodible material will remain unaffected by laboratory fumes.

Sensitivity and accuracy are imparted by the precise placing of the rust-proofed knife edges on polished agate bearings in the carefully balanced parts. Loads up to the full capacity are accurately weighed to 0.02% . . . with light loads to $^1/_{10}$ gram.

3470 **CENCO TRIP SCALE, Single Beam,** 5000 gram capacity with rider weight on a beam graduated to 10 grams in $^1/_{10}$ gram divisions..... **Each $8.55**

9125D **Weights, Metric,** for use with No. 3470 Trip Scale. Made of lacquered brass and contained in wood block. Smallest value, 1 gram. Largest value, 1000 grams..... **Per set $6.75**

3560 **CENCO TRIP SCALE, Double Beam,** same as No. 3470 Trip Scale, but with additional beam and rider weight for weighings up to 2000 grams in steps of $^1/_{10}$ gram..... **Each $10.00**

9126 **Weights, Metric,** for use with No. 3560 Trip Scale. Same as No. 9125D Weights, but consisting of two 200, one 500, and one 1000 gram weights in wood block..... **Per set $6.30**

3620 **CENCO TRIP SCALE, Triple Beam,** for weighings up to 1110 grams in steps of $^1/_{10}$ gram without the use of loose weights. No. 3620 Attachment Weight extends range to 2110 grams..... **Each $10.45**

CENTRAL SCIENTIFIC COMPANY

CHICAGO
1700 Irving Park Blvd.
Lakeview Station

SCIENTIFIC INSTRUMENTS

TRADE MARK CENCO REG. U.S. PAT. OFF.

LABORATORY APPARATUS

BOSTON
79 Amherst St.
Cambridge A Station

New York • Boston • CHICAGO • Toronto • San Francisco

READY FOR YOU NOW!

A NEW, ENLARGED AND COMPLETELY REVISED

"PYREX" LABORATORY GLASSWARE CATALOG

PRESENTING 358 NEW ITEMS
AND TWO NEW LINES

VYCOR BRAND LABORATORY WARE (TRADE MARK VYCOR REG. U.S. PAT. OFF.)

PYREX BRAND FRITTED WARE (T.M. REG. PYREX U.S. PAT. OFF.)

•This new 160-page Catalog is the most comprehensive listing of laboratory glassware we have yet published. It lists approximately 2700 items of which 358 are new. Included is a complete listing of the items available in the new PYREX brand Fritted Ware, as well as the VYCOR brand Ware fabricated from the new 96% silica glass No. 790.

Prices have been reduced on a number of items. Consumer quantity discounts apply to practically all items when ordered in full original packages, except for a few items which are packed one piece per package. Further economies can be realized if ware is purchased in assortments of 20, 50, or 100 original packages. All items listed are available through your regular laboratory supply dealer.

CORNING GLASS WORKS • CORNING, N. Y.

MAIL THIS COUPON NOW!

Please forward to me a copy of the new "PYREX" Laboratory Glassware Catalog, No. LP-21.

*Name*_____ *Position*_____

*Company or Institution*_____

*Address*_____

*City*_____ *State*_____

Please place my name on your regular mailing list ☐

CORNING *means* Research in Glass

Pyrex Laboratory Ware
BRAND

Vitamins B_1, B_2

Apparatus according to the Combined Method for the Determination of Riboflavin and Thiamin on the same sample

Ref: Technical paper by Dr R T Conner and Dr G J Straub given at the A.C.S. Meeting, St Louis, Mo., April 7th, 1941

We offer a complete selection of standard, as well as specially designed equipment for vitamin analysis. The Constant Reflux Apparatus, Reaction Vessel, Vacuum Receiver and Base Exchange Tube have been designed for the Combined Analysis of B_1 and B_2 referred to above.

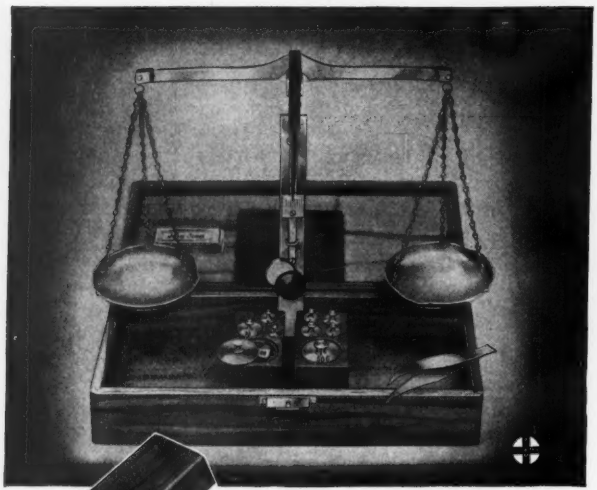
An 8-page bulletin entirely devoted to equipment for vitamin analysis, including the new Coleman Fluorescence Meter, is available.

Food manufacturers not maintaining a chemical laboratory at present will find this bulletin extremely valuable in setting up for vitamin analysis and control.

SCIENTIFIC GLASS APPARATUS CO.
BLOOMFIELD, N. J

A COMPACT INEXPENSIVE BALANCE

for every Student



Now you can equip each student with a balance and weights on which all the experiments involving balance technique can be performed.

The Adams Compact Balance and a complete set of weights are enclosed in an attractive compact box which is easily stored in a laboratory drawer when not in use.

To use the balance, the upright beam support is inserted into the metal socket in the box, and the beam is placed on it. An eccentric beam release with knob sets the pans at rest for addition of weights. The pointer carries a movable bar for adjustment of the zero point.

The use of ADAMS COMPACT BALANCE . . .

- Enables each student to have a balance which is used at his laboratory bench, thereby reducing waste motion and confusion.
- Reduces departmental costs for balance maintenance.
- Improves student technique.

No. A-2165/B ADAMS IMPROVED COMPACT BALANCE, Model 1940

Complete in case with Metric or Troy weights and forceps as described. **Each $12.00.**
Quantity discounts on request.

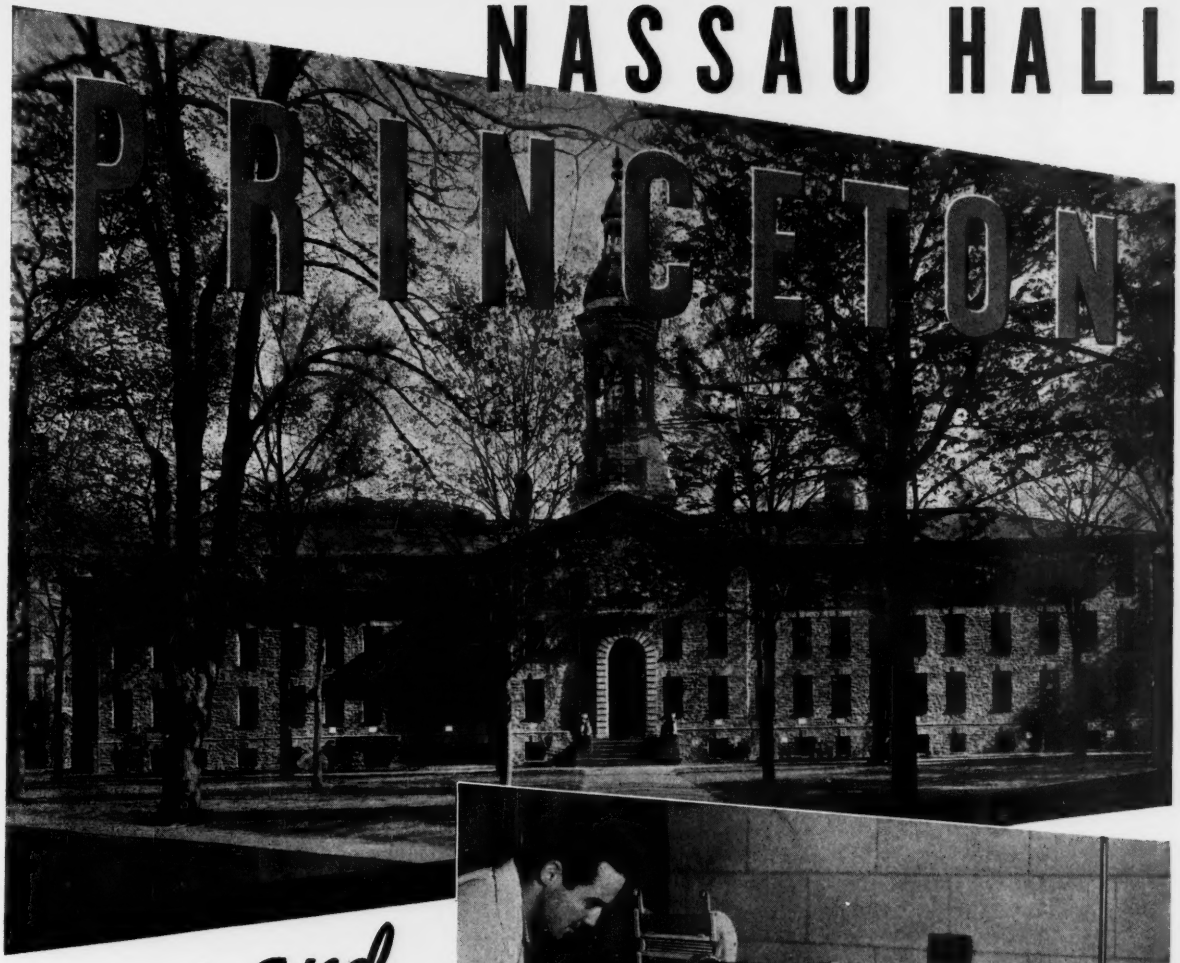
Specifications . . .

Capacity 100 grams, sensitivity 10 mg. Supplied with lacquered brass weights and square form aluminum fractions, 50 grams to 10 mg., and weight forceps . . . in natural finish sap gumwood box, 10" x 14¼" x 2". Beam is 7¼" long and carries a steel knife edge which engages an agate bearing on the beam support. Pans are 3¼" . . . notched to hold test tubes. Metal parts are brass and heavily chromium plated. Made in U.S.A.

We will gladly send you literature or a balance on approval. Please write

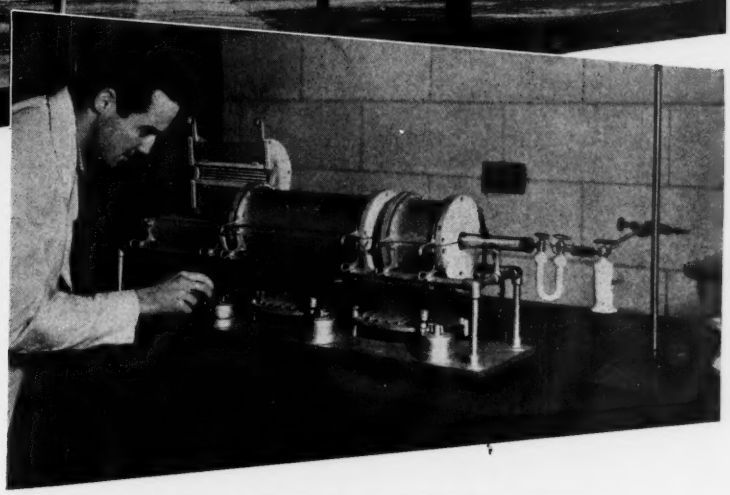
CLAY-ADAMS CO., Inc. 44 East 23rd St. New York, N. Y.

NASSAU HALL PRINCETON



and

HEVI DUTY FURNACES



One hundred and forty-five years ago the first chemical laboratory in the world for undergraduates was established at Nassau Hall by Dr. John Maclean. Nassau Hall still stands as a monument to this cradle of chemical education though the fine Frick Chemical Laboratory now houses new modern laboratory equipment. It is gratifying to us to note that Princeton, like many other leading universities, uses Hevi Duty Laboratory Furnaces for chemical study and analysis.

HEVI DUTY ELECTRIC COMPANY

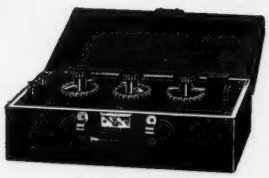
HEAT TREATING FURNACES HEVI DUTY ELECTRIC EXCLUSIVELY

MILWAUKEE, WISCONSIN

One Ohm Standard

A-C Resistance Box

Brooks Inductometer



Mica Capacitor

Eppley Standard Cell

L&N STANDARDS OF RESISTANCE, INDUCTANCE, CAPACITANCE AND POTENTIAL

D-C RESISTORS

4210 ONE-OHM STANDARD RESISTOR—Adjusted to approx. value of Absolute Ohm. N.B.S. will certify to ±0.0001% in terms of the Washington Ohm, $100.00, plus N.B.S. certif.

N.B.S. TYPE RESISTORS—Limit of error: ±0.01% up to 0.1 watt; ±0.04% up to 1 watt. 4020, 1 ohm, $20.00; 4025, 10 ohms, $20.00; 4030, 100 ohms, $20.00; 4035, 1000 ohms, $20.00; 4040, 10,000 ohms, $25.00.

REICHSANSTALT TYPE RESISTORS—Limit of error, cooled in oil: ±0.02% up to 1 watt; ±0.05% up to 10 watts. 4221, 0.1 ohm, $50.00; 4222, 0.01 ohm, $55.00; 4223, 0.001 ohm, $120.00.

RESISTORS (SHUNTS) FOR LARGE CURRENTS—Limit of error, air cooling, ±0.04%.

	Ohm	Amps.	Volts Drop	
4360	0.1	15	1.5	$ 55.00
4361	0.01	100	1.0	100.00
4363	0.001	300	0.3	90.00
4364	0.001	500	0.5	175.00
4369	0.00004	1,500	0.06	187.00
4372	0.00002	2,000	0.04	187.00
4375	0.00001	3,000	0.03	300.00

SECONDARY-STANDARD RESISTORS—Limit of error ±0.1%. 4205, 1 ohm, $10.00; 4206, 10 ohms, $10.00; 4207, 100 ohms, $10.00; 4208, 1000 ohms, $10.00; 4209, 10,000 ohms, $10.00.

4245 TENTH-MEGOHM RESISTOR — 100,000 ohms. Limit of error ±0.1%, $50.00.

OPEN-DIAL-SWITCH RESISTANCE BOXES *††

No	Ohms	Dials	Decade Steps	Price
4710	100	3	10x0.1+9(1+10)	$75.00
4711	1000	3	10x1+9(10+100)	70.00
4712	10000	3	10x10+9 (100+1000)	80.00
4715	1000	4	10x0.1+9 (1+10+100)	95.00
4716	10000	4	10x1+9(10+ 100+1000)	100.00
4720	10000	5	10x0.1+9(1+10+ 100+1000)	125.00

ENCLOSED-SWITCH RESISTANCE BOXES—For commercial-power frequency a-c as well as d-c.*†

No.	Ohms	Dials	Decade Steps	Price
4770	99	2	9(1+10)	$21.00
4771	990	2	9(10+100)	21.00
4772	9900	2	9(100+1000)	21.00
4773	999	3	9(1+10+100)	28.00
4774	9990	3	9(10+100+1000)	29.00
4775	9999	4	9(1+10+100+ 1000)	35.00
4776	999.9	4	9(0.1+1+10+100)	35.00

4452 PLUG-DECADE RESISTANCE BOX — 19,-999.9 ohms. 9(0.1+1+10+100+1000)+10,000,*†† $110.00.

4252 POST-OFFICE PATTERN RESISTANCE BOX—11,110 ohms in steps of 1 ohm. Adjusted by removing plugs. Resistors 1, 2, 3, 4, 10, 20, 30, 40, 100, 200, 300, 400, 1000, 2000, 3000, 4000 ohms,*† $36.00.

*D-C res., with all dials or plugs at zero, does not exceed 0.03 ohm.

**D-C res., with all dials at zero, does not exceed 0.04 ohm.

†D-C res. change from zero setting, measured across binding posts, equals the readings of the dials ±(0.1%+0.01 ohm).

††D-C res. change from zero setting, measured across binding posts, equals the readings of the dials ±(0.05%+0.005 ohm).

Jrl Ad E(17)

4254 POST-OFFICE PATTERN RESISTANCE BOX—Similar to 4252, but 1,110 ohms. Resistors 1, 2, 3, 4, 10, 20, 30, 40, 100, 200, 300, 400 ohms, $30.00.

4244 MEGOHM RESISTANCE BOX — 1,000,000 ohms (4x200,000+2x100,000). Limit of error in resistors ±0.1%, $200.00.

4246 TENTH-MEGOHM RESISTANCE BOX—100,-000 ohms (10,000+20,000+30,000+40,000). Limit of error in resistors ±0.1%. Binding posts on ring mounted on insulating pillars, $90.00.

4247 TENTH-MEGOHM RESISTANCE BOX—Same as 4246 except, binding posts equipped with link connectors, $65.00.

A-C RESISTORS

SECONDARY-STANDARD A-C RESISTORS—Limit of error in d-c res. ±0.1%. Difference between a-c and d-c res. less than ±0.001% at 1 kc, less than ±0.01% up to 50 kc. 4631, 1,000 d-c ohms, $13.00; 4632, 2,000 d-c ohms, $13.00; 4633, 3,000 d-c ohms, $14.00; 4634, 4,000 d-c ohms, $14.00; 4640, 10,000 d-c ohms, $15.00; 4642, 20,000 d-c ohms, $17.00.

A-C RESISTANCE BOXES — Total 11,111.1 ohms. 10(0.01+0.1+1+10+100+1000). 6 dials, shielded. Differ principally in A-C characteristics. 4764*††, $300.00; 4765*††, $270.00; 4750**††, $100.00; 4749*†, $90.00.

A-C RESISTANCE BOXES—Total 11,110 ohms. 10(1+10+100+1000). 4 dials. 4748*††, shielded, $65.00; 4747*†, shielded, $55.00; 4746*††, unshielded, $60.00; 4745*†, unshielded, $50.00.

ATTENUATORS—Information on request.

INDUCTORS

STANDARDS OF SELF INDUCTANCE — Time const. approx. $1x10^{-3}$. Limits of error; 1530,± 1%; 1531, 1532, 1533, ±0.2%; 1530, 1 mh, 1 amp., $30.00; 1531, 10 mh, 0.5 amp., $30.00; 1532, 100 mh, 0.15 amp., $30.00; 1533, 1,000 mh, 0.05 amp., $30.00.

1540 STANDARD OF MUTUAL INDUCTANCE—50 mh. Continuous current capacity 0.15 amp. Time const. approx. $5x10^{-4}$. Limit of error ±0.5% for freqs. up to 1000 cy., $40.00.

1520-A BROOKS INDUCTOMETER—Self-inductance range 1.5 to 12 mh. Continuous current capacity 1 amp. Time const. for max. setting, approx. $2x10^{-3}$. Limit of error ±0.3% of max. inductance for freqs. up to 1000 cy, $150.00.

1520-B BROOKS INDUCTOMETER—Self-inductance range 12 to 100 mh. Continuous current capacity 0.35 amp. Otherwise same as 1520-A, $150.00.

1520-C BROOKS INDUCTOMETER—Self-inductance range 100 to 800 mh. Continuous current capacity 0.1 amp. Time const. for max. setting, approx. $2x10^{-3}$. Scale calibrated at 1000 cy; correction data furnished for 60 cy. Limit of error ±0.3% of max. inductance at each of these freqs., $150.00.

1520-D BROOKS INDUCTOMETER—Self-inductance range 0.8 to 6 henrys. Continuous current capacity 0.03 amp. Limit of error ±0.9%. Otherwise same as 1520-C, $150.00.

CAPACITORS

1056 FIXED MICA CAPACITOR—0.5 mf. Limit of error ±0.25%, $30.00.

1061 ADJUSTABLE MICA CAPACITOR—1 mf, in 8 sections: 0.5, 0.2, 0.1, 0.1, 0.05, 0.02, 0.02, 0.01 mf. Limit of error for each, ±0.25%, $200.00.

1058 ADJUSTABLE MICA CAPACITOR—1 mf in 5 sections: 0.5, 0.2, 0.2, 0.05, 0.05 mf. Limit of error ±0.25%, $65.00.

1071 THREE-DIAL SHIELDED MICA CAPACITOR—1.11 mf in steps of 0.001 mf. 10(0.1+0.01+0.001). At 1,000 cy, capacitance diff. between each dial setting and its zero setting (other dials on zero) agrees with nominal ±(0.1%+0.5mmf), $325.00.

1070 THREE-DIAL MICA CAPACITOR—1 mf in steps of 0.001 mf. 9(0.1+0.01+0.001)+0.001. Limit of error 0.1 dial, ±0.25%; 0.01 dial, ±0.5%; 0.001 dial, ±2%, $175.00.

1188 ADJUSTABLE AIR CAPACITOR — Minimum, 50 mmf. Range 50 to 1,300 mmf on 2 dials: one reads up to 1,200 mmf in 100 mmf steps; other, 0 to 100 mmf, continuously adjustable. Quartz insulators, $170.00.

1187 ADJUSTABLE AIR CAPACITOR — Same as 1188, but has isolantite insulators, $150.00.

1185 ADJUSTABLE AIR CAPACITOR — Range approx. 40 to 1,100 mmf. Scale 0 to 100 div. Limit of error ±5 mmf, $30.00.

1170 HIGH-VOLTAGE ZERO-LOSS AIR CAPACITOR—For use up to 100,000 volts. Capacitance (adjustable) approx. 100 mmf at 12-inch (100-kv) spacing. Has guard circuit. Approx. 12'x7'x10'. Price on request.

1160 10-KILOVOLT CYLINDRICAL TYPE AIR CAPACITOR—Approx. 100 mmf. Max. continuous potential rating 10,000 volts at 60 cy. Electrostatically shielded. Low-voltage electrode guarded, $575.00.

1161 25-KILOVOLT CYLINDRICAL TYPE AIR CAPACITOR—Same as 1160, except: max. continuous potential rating 25,000 volts at 60 cy, $775.00.

STANDARD (POTENTIAL) CELLS

7308 EPPLEY STANDARD CELL—Not over 500 ohms. Emf guaranteed within ±0.01% of certified value, $20.00.

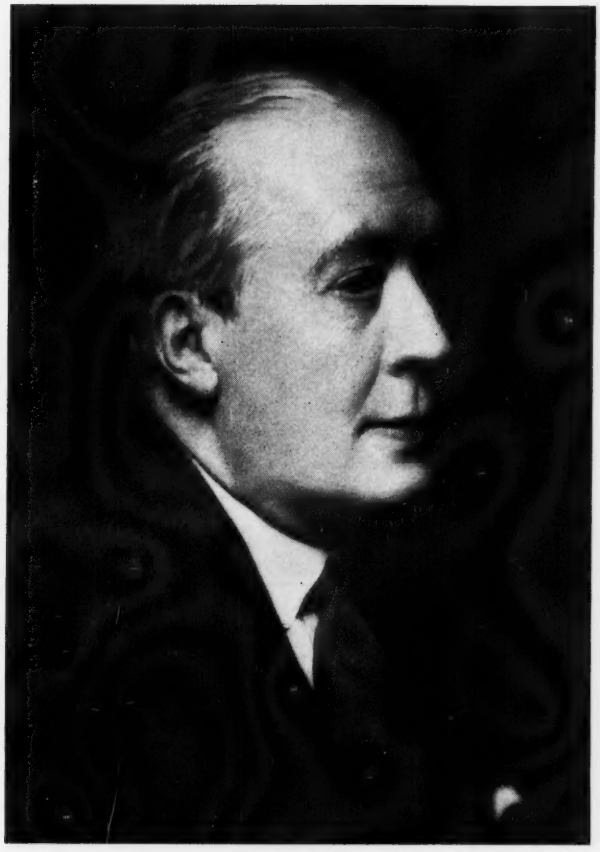
7309 EPPLEY STANDARD CELL — Same as 7308, except internal res. not over 100 ohms, $25.00.

7310 EPPLEY STANDARD CELL—Not over 500 ohms. Emf 1.018 volts, within ±0.1% at 20 C, $12.00.

LEEDS & NORTHRUP COMPANY, 4976 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

Measuring Instruments · Telemeters · Automatic Controls · Heat Treating Furnaces



Frederick George Donnan
(1870–)

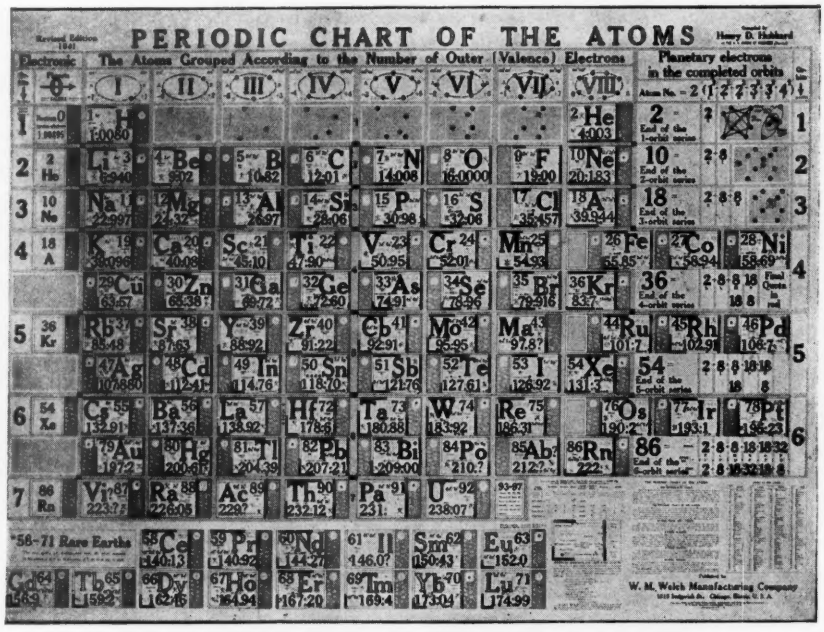
Contributed by R. E. Oesper, University of Cincinnati

(For biographical sketch of Frederick George Donnan, see page 282.)

BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS
LIBRARY

A New
1941 CHART OF THE ATOMS

Compiled by Henry D. Hubbard—U. S. Bureau of Standards


PERIODIC CHART OF THE ATOMS
Henry D. Hubbard
The Atoms Grouped According to the Number of Outer (Valence) Electrons
Planetary electrons in the completed orbits
W. M. Welch Manufacturing Company

No. 4854

COMPLETELY REVISED—1941

This 1941 Edition represents an extensive revision under the supervision of Dr. W. F. Meggers of the U. S. Bureau of Standards. Every bit of information on the chart is brought up to this date. The latest information on the isotopes of each element appears on the chart with a new and more complete method of representing them.

LITHOGRAPHED IN 6 COLORS

The chart is lithographed in six colors and all routine information is printed in large type so as to stand out distinctly. The *atomic number* is red; the *atomic weight* is black; and by a color differentiation the large size atomic symbol indicates that the element is a solid, liquid, or gas at ordinary temperatures. *40* different characteristics of the atom are shown.

YOUR LABORATORY DESERVES THIS UP-TO-DATE CHART

An old Chart of the Atoms in the laboratory is like an old railroad time table at the station; or an out-of-date basketball rule book in the gymnasium. It may be correct in some details but not in all. Your classes deserve the latest reference material. There have been hundreds of changes since the 1924 edition.

The Chart is backed by cloth and is mounted on double split rollers top and bottom. Complete with explanatory booklet.

$5.—NO INCREASE IN PRICE—$5.

W. M. WELCH SCIENTIFIC COMPANY

Established 1880

1516 Sedgwick Street — Chicago, Illinois, U.S.A.

Editor's Outlook

STRANGE how Spring brings out the optimistic side of our natures. Not only do flowers bloom in the spring (tra la!), but also our hopes and aspirations. It even reflects itself in our teaching—if we are serious enough about that to let it be affected by our state of mind. After struggling through a whole school year, trying to lead a class through the intricacies of chemistry, we reach this season with mixed emotions. Probably we share with the students a sense of relief at the approaching end of the "grind"; perhaps we feel a little proud of our students' accomplishments as a result of (or despite) our efforts; very likely we look forward to another year, which we feel sure will be more fruitful, because we, too, have learned some things. This last is an interesting point, for there is one thing which we never seem to be able to learn. Vaguely, we think: "There now! We've got all those troublesome little things straightened out. With this as a start we can really go places next year." Alas, no! Next year will bring a new crop of green material, with the same problems, mental, emotional, pedagogical. The only difference will be that *we*—perhaps—will be a little better equipped to meet them. Too bad that next year's class can't begin where this one leaves off.

If you are discouraged by this thought you should not be teaching. You must accept it as a challenge—a challenge to improvement year after year, in face of the recurrence of the same situations again and again. A continuing program of creative work, carried on simultaneously, is generally the balancing element which prevents us from becoming dizzy and stupid from the eternal cycle of things.

THE enrolment figures in the federal vocational training program, so largely stimulated by the present emergency, are indeed very encouraging, if we take them at their face value. It is comforting to know that so many thousands of men are being rapidly trained to carry out the highly technical jobs in commerce, agriculture, and industry which are essential to bringing us through the troubled times ahead. But let no one assume that this is more than an emergency measure. War times are inevitably boom times, but, thank God, abnormal. With more jobs opening up every day than there are trained men to fill them we must perforce resort to high-pressure technic to meet the situation. But some day—may we hope—it will again be unnecessary for men to weld the top-plates onto military tanks, or to machine the breech-blocks for Bren guns (if that is what they have), and then the men who have been trained for these particular jobs will have to find other outlets for their particular mechanical skills. Very likely they will be able to do so, although perhaps only after a painful period of dislocation. Even in normal times industry can doubtless absorb a larger number of mechanically minded workers.

But there is a danger in assuming that this high-pressure training is real education. In the old argument between the liberal educators and the vocational training enthusiasts there is no doubt as to who is now in the lead. Liberal education, like democracy, may soon be fighting for its life. A six weeks' training course in welding may be an effective way to fit a man to occupy a niche but he can hardly hope to be anything but a niche-sitter all the rest of his life.

To be sure, the various niches must be occupied, but every niche-sitter should have something in his mental equipment with which to concern himself while he sits. And this is the function of a liberal education. It should make one more than merely self-sufficient. No doubt the ideal condition would be for everyone to be so much bigger than his niche that he bulges out all around it. Let the sociologist worry as to whether this would result in as much discomfort socially as the metaphor would suggest physiologically.

Anyway, the point to all this is the bearing of the present crisis upon liberal education. It would be a shortsighted policy to permit our system of higher education, with its liberal as well as its vocational elements, to be largely dislocated. Liberal education is not a luxury, nationally or individually; it is part of our social structure, as much a social institution as church, home, or state. In taking up arms we must not abandon the thing we are fighting for.

Specifically, what is to be the relation of Selective Service to college students? Elsewhere in this issue are statements quoted from Selective Service officials showing that they accept, for the most part, the principle that higher education should not be interfered with, any more than necessary. Other popular movements are under way to extend this principle even further. It cannot be denied that, by and large, our public leadership comes from our colleges and universities, and it is appallingly evident that we need leadership above all.

This does not imply a cloistered immunity from military service for all college students, but rather an assurance of the opportunity to complete their courses to the point of utmost public service, as well as an assurance that their training and capabilities will actually be put to the most efficient use thereafter.

It has repeatedly been argued that there are more students in our colleges than ought to be there. If this is true the situation will adjust itself without any drastic pressure from outside. Enrolments will fall off somewhat, but in a more or less natural way, without the anxious uncertainty which is growing now. Then our colleges can concentrate upon the most important job before us: a study and evaluation of the whole world situation, future as well as present. This is the thing for which we must prepare competent leadership. It cannot be done efficiently as long as this spectre hangs over our college campuses.

If this seems inconsistent with our ideas of de-

(*Continued on page 297.*)

What's Been Going On

PHENOTHIAZINE, which was reported six years ago by Dr. L. E. Smith of the Department of Agriculture to be an effective insecticide, now finds use in combating worms in sheep, swine, and horses. It is also effective against the larvae of horn flies and mosquitoes.

During 1940 it was reported that coal and oil can be made in the laboratory from plant carbohydrates, thus accomplishing in a few hours what has taken nature a long, long time to synthesize. Another feat of the year is the laboratory duplication of the "natural process by which glucose is converted by plants into starch."

According to *Research and Invention*, there are now some 9000 uses for paper. One of the newer developments is Pervel, which is a chemically treated paper possessing the appearance and feel of cloth. Pervel is being marketed in the form of aprons, curtains, pillow slips, and similar commodities, all of which are used until soiled and then discarded.

Shrink-proof ladies' gloves, which resemble heavy silk in appearance and texture, are being produced from nylon by Crocetta Brothers, Gloversville, New York.

Parthenocarpy is the art of injecting the pollen of one plant into the ovary of another plant to effect the production of a seedless fruit. The first success was achieved by Yasuda in 1934. Chloroform extracts of pollen, as reported by Gustafson in 1937, initiate growth of the ovary in certain cases, and produce seedless fruit. In the same year Gardner and Marth produced seedless fruit by treating the American holly bloom with indoleacetic, indolepropionic, indolebutyric, or naphtholacetic acids. In 1938 Gustafson obtained parthenocarpic fruits from a variety of plants by treating the bloom with potassium indoleacetate, or pyrolacetic acid, or pyrolcarboxylic acid. Wong, in 1939, obtained seedless cucumbers, seedless peppers, and seedless watermelons by the use of naphthaleneacetic acid.

Vitamin H, which appears to be identical with biotin and coenzyme R, is a member of the B group and has the rather curious property of protecting against injury caused by egg white in the diet, as indicated by studies on baby chicks.

Glass fiber is sufficiently flexible, readily sterilized, and absorbed slowly by the body, all of which seems to point to its use in surgery.

Denicron is the new du Pont fiber, which may be woven into a fabric closely resembling wool cloth. It has good tensile strength, retains delicate colors well, and absorbs fireproofing chemicals readily. It seems particularly well adapted to the upholstery trade.

Ursolic acid, worth about $80 an ounce, is now being obtained from the cranberry.

A product similar to nylon is being produced in Germany under the trade name of Perluran.

Experiments by Dr. Agnes Fay of the University of California indicate that ordinary silver foxes, when deprived of one of the vitamins of the B group, yield furs of the platinum variety. Unfortunately, the furs produced in preliminary experiments are not as durable as are those of the Norwegian variety.

One of the newer applications of Lucite is in the production of a corrosion-resistant knife that is particularly adapted to carving fruits and cake.

Urea is a satisfactory substitute for soy-bean oil meal in sheep rations, according to the work of Kammlade, Mitchell, and Bull of the University of Illinois. As a result of their findings and work at Massachusetts Agricultural Experiment Station and Wisconsin, the control officials have authorized the use of urea in feeds for ruminants.

Polyvinyl chloride fiber is being rechlorinated in Germany to give a product known as Pe-Ce-silk. It is claimed that this fiber is over five times as durable as cotton or wool in filters. It is finding use in the fabrication of fish nets, rope, and protective clothing.

Effective sterilization of air by the use of a germicidal mist, in which propylene glycol is the carrier, has been reported by the Medical School of the University of Chicago. This appears to be the first successful attempt to sterilize the air.

Triptane (2,2,3-trimethylbutane, which has an octane rating of about 125) is being produced in England by the dehydration of 2,2,3-trimethyl-3-butanol and subsequent hydrogenation.

Staple fiber is being produced in Germany from wheat and rye straw.

During the production of calcium gluconate by the fermentation process, the addition of a trace of boric acid or borax holds the salt in solution until the fermentation is complete. Subsequently, the gluconate is separated from the solution, free from boron.

Sodium, with the exception of iron, is now the world's cheapest metal on a unit volume basis. The annual world production of sodium now exceeds 300,000 tons. The important role played by aluminum, copper, magnesium, and sodium is a direct outgrowth of electrochemistry.

The world's total stock of radium, valued at $18,000,000, amounts to about two pounds.

Even the rabbit has been drawn into the present international muddle, as evidenced by the fact that rabbit skins are being used in Germany for belts, for handbags, and for uppers of wooden-soled shoes.

The chemist has contributed in no small part in extending the life expectancy of a child at birth from about 25 years during the early Christian era to 60 years in 1940. By 1960, it is thought that this figure may be raised to about 75 years.

The total potential supply of propane and butane in the United States refineries and gasoline plants is about nine billion gallons per year. Of this amount nearly half a billion gallons are being used as liquefied petroleum gas and about three and one-half billion gallons are used annually in the production of gasoline.

Intensive research to develop plants that "bugs don't like" is under way in the states of California, Illinois, Indiana, Missouri, Ohio, Oklahoma, Texas, Wisconsin, and Kansas. "The idea is to make the plant do its own fighting by being so disagreeable to the attacking insects that they will seek their dinners elsewhere and even starve." It is hoped that these plants, although untouchable to devouring insects, will be "tasty and nutritious to man and beast for whom they are raised as food."

Sterilized fabrics, according to the *Research Viewpoint*, are soon to be available. It is claimed that these fabrics will "be odorless and completely non-irritating to the skin."

Developments in the B group of vitamins during 1940 included (*a*) experimental evidence that riboflavin is a cure for keratitis, and (*b*) the synthesis of pantothenic acid and its identification "as an adrenal gland-protecting factor for rats."

Flexseal is the trade name of a new safety glass, developed by the Pittsburgh Plate Glass Company, which has a strength about ten times that of ordinary automobile safety glass. The sandwich plastic is of the vinyl type and extends beyond the edges of the glass to give added protection and at the same time provide simple mechanical means for mounting. It can be bolted, screwed, or even nailed into openings.

Cigarette paper, formerly imported almost entirely from Europe, is now being produced from flax fiber by a mill which started operation at the outset of the present war. Currently this mill is supplying about one-third of the cigarette industry's paper requirements and is expanding with sufficient rapidity that the entire demand will be taken care of when the current stocks of French paper are depleted.

Results obtained by the National Institute of Health indicate that at least some of the effects of sulfanilamide may be closely related with the dietary. Increase in protein intake seems to increase the toxicity and decrease the effectiveness of the medicinal.

(*Continued on page 282.*)

Bunsen's Trip to Iceland

As Recounted in Letters to His Mother[1]

RALPH E. OESPER *University of Cincinnati, Cincinnati, Ohio*

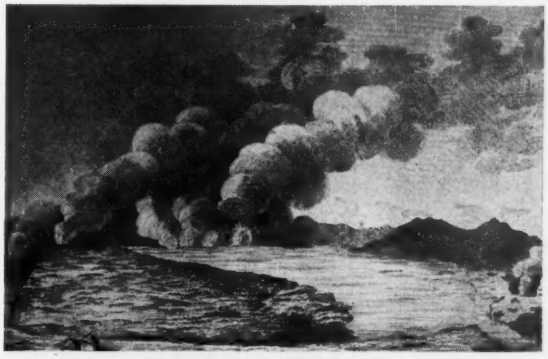
KARL FREUDENBERG *University of Heidelberg, Heidelberg, Germany*

"Volcanoes have a splendor that is grim,
And earthquakes only terrify the dolts;
But to him who's scientific
There's nothing that's terrific
In the falling of a flight of thunderbolts."
—W. S. Gilbert, "The Mikado"

THE exceptionally violent volcanic outbreak on Iceland in the summer of 1845 led the well-known traveler and scientist, (Wolfgang) Sartorius von Waltershausen, to propose to the Danish government that a scientific expedition be sent to the island to study the eruption, and also the geysers and hot springs that are due to the same causes as the volcanoes. The authorities willingly supported the plan and placed all facilities at the disposal of the party, which consisted of von Waltershausen, who acted as director; the French mineralogist, Alfred Descloizeaux (Des Cloizeaux); Robert Bunsen, who was then Professor of Chemistry at Marburg; and his colleague the mineralogist, Bergmann.

"Connected with the Icelandic expedition the following story is told: Bunsen had made all his arrangements for the expedition, had packed all the apparatus required to carry on an experimental research in those regions, but he had been unable to obtain from the Kurfürst of Hesse-Cassel, of whose Civil Service he was a member, leave of absence from his professorship, although the application had been made repeatedly. In this difficulty, he appealed for help to a cousin who happened to be domestic physician to this Prince, whose eccentricity was well known. The difficulty was solved as follows: the physician informed His Royal Highness that a cousin of his, who was professor of chemistry in the Marburg University, had conceived the wild idea of voyaging to Iceland, and that this was regrettable inasmuch as the professor would inevitably lose his life in so dangerous an undertaking, consequently he hoped that His Royal Highness would not accede to the request. The result of the interview was that the documents so long waited for were in Bunsen's hands the next day."[2]

The expedition was in Iceland from the middle of May to the end of August, 1846[3]; its members made a host of scientific observations and brought back numerous specimens. For example, Bunsen collected several hundred samples of the atmosphere at sea, at Reykjavik, and near the Arctic Circle, in order to compare the oxygen content with that of samples taken at the same time in Copenhagen and Marburg. He was particularly interested in the gases emitted by the active volcanoes and hot springs, and more than one hundred samples were taken back to his laboratory for analysis. An adequate number of samples of the rocks, lava, etc., were collected, and later analyzed. Out of this expedition came a series of papers by Bunsen; they were published from 1846 to 1851.[4] These Iceland studies are still counted as extremely important and fundamental contributions to petrology and chemicogeology. For instance, he and Des Cloizeaux made a series of measurements of the temperature of the water at various levels in the geyser tubes and these data formed the basis of the first satisfactory explanation of geyser action, a theory that is still substantially ac-



From "Iceland, or the Journal of a residence on that island during 1814 and 1815," by E. Henderson, Edinburgh, 1818

HOT SPRINGS

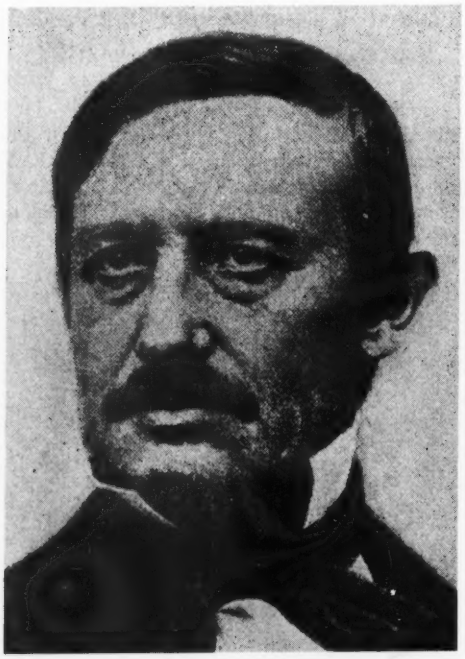
[1] Presented before the Division of the History of Chemistry at the 100th meeting of the A. C. S., Detroit, Michigan, September 12, 1940.

[2] ROSCOE, "Bunsen memorial lecture," Memorial Lectures delivered before the Chemical Society, 1893–1900, p. 535.

[3] The Yellowstone geysers were first seen by a white man in 1807. The descriptions by later visitors were largely received with incredulity. The region was practically unknown until 1870, when a semiofficial expedition made the Yellowstone Wonderland widely known.

[4] See OSTWALD AND BODENSTEIN, Editors, "Gesammelte Abhandlungen von Robert Bunsen," Engelmann, Leipzig, **1904**, Vol. II, pp. 1–171 for reprints of the Iceland papers, which originally appeared chiefly in LIEBIG'S *Annalen* and POGGENDORF'S *Annalen;* see also DES CLOIZEAUX, *Ann. chim. phys.*, [3] **19**, 444 (1847). For technical discussions see RATHKE, *Z. anorg. allgem. Chem.*, **23**, 401 (1904); OSTWALD, "Robert Bunsen," Feuer Verlag, Leipzig, **1905**, p. 13; DEBUS, "Allgemeine Deutsche Biographie," Duncker und Humblot, Leipzig, **1903**, Vol. 47, p. 372. Translations of two of the most important papers are available: (1) "On the intimate connection existing between the pseudovolcanic phenomena of Iceland," in "Cavendish Society, chemical reports and memoirs," edited by HARRISON, London, **1848**. Reprinted in *Science News Letter*, **18**, 262 (1930); (2) "On the processes which have taken place during the formation of the volcanic rocks of Iceland," in "Scientific memoirs selected from the *Transactions* of foreign Academies of Science and from foreign journals," Taylor and Francis, London, **1851**. See also: "On some of the eruptive phenomena of Iceland," a lecture by TYNDALL, June 3, 1853, *Proc. Roy. Inst.*, **1**, 329 (1851–54). Bunsen's article on palagonite (*Ann.*, **61**, 265 (1847)), together with his work on cacodyl derivatives, won for him the Copley medal, *Proc. Roy. Soc. London*, **11**, 14 (1860).

cepted. Bunsen's observations gave him the foundations of other shrewd and important conclusions. Unfortunately, the majority of modern chemists have never read these papers.



LEADER OF THE ICELAND EXPEDITION
WOLFGANG SARTORIUS (FREIHERR) VON WALTERSHAUSEN (1809–76)

Some derogatory remarks by the leader of the expedition goaded Bunsen, that least boastful of all men, into publishing a statement about the physical discomforts and actual hazards he had endured in order to gather his samples and data.

"Waltershausen knows that I devoted most of my stay on Hekla to the study of the fumaroles there; the bloody traces of my hands more than once told him the extent of the efforts with which I followed the limits of the various vents into the sharp-edged broken masses and slag heaps; he knows that I carried out the most painstaking experimental studies in the midst of these steaming springs; he knows that I pursued these experiments on the fumaroles beyond the back of the crater into the deepest of the new Hekla craters, that crater whose floor and whose deeper fumarole fields only M. Des Cloizeaux and I had the privilege of reaching; he certainly has not forgotten the time that we met high up on Hekla at the snow-line, that time when one of those furious dust storms brought down the tent over our heads and made us leave quickly, ..."[5]

Christian Bunsen, the chemist's father, was Professor of Modern Philology and Librarian at Göttingen. After his death in 1837, his widow moved to Hanover, where her other two sons held government posts.[6] Bunsen, who never married, was devoted to his mother, and it was one of his great regrets that her death (1853) came before he acquired his full reputation in the chemical world. "The only value such things (his decorations and honors) had for me was that they pleased my mother, and she is now dead."

The letters to her describing his experiences on this Icelandic expedition clearly reveal this filial devotion, and show the essential simplicity of the great chemist's nature. They not only give interesting sidelights into this important scientific undertaking, but exhibit also Bunsen's ability in the fine art of letter writing. Some passages of merely transient family interest have been omitted in this translation, and Bunsen's Germanic spelling of place names has been changed to more widely accepted forms. The letters, along with other important Bunseniana that still await publication, are preserved in the Library of the University of Heidelberg.

I

Copenhagen, April 25, 1846

Dearly beloved Mother:

In spite of all my efforts to get a little free time for you, not until now have I found it possible finally to get away from this whirl of entertaining, visits, and errands, to tell you something more definite and in more detail about the journey that we have already made, and the one we are going to make. Our affairs here are in far better shape than we could have hoped them to be and all signs point to the success of our enterprise.

On Sunday, the 19th, Bergmann and I, after a slightly uncomfortable crossing, arrived in the harbor here, where our good friend Sartorius was waiting for us on the wharf. The King is most keenly interested in our expedition and already has ordered that our arrival be announced to him by Lieutenant Mathissen, who has been assigned to us during our stay here and who is to represent the government during the Iceland trip. As early as the 21st, I, along with Bergmann, had a rather lengthy audience with the King, who received us in a most friendly manner.

Sartorius had already been received in the same way and soon after his arrival. The King[7] is a stately elderly gentleman with an extremely kindly, almost flattering air, and he immediately inquired if Lieutenant Mathissen had followed his orders and shown us the sights of Copenhagen. Since he is more than a dilettante in oryctognosy [mineralogy], and quickly turned the conversation to the special objects of our trip, I was able to talk about several matters that seemed to interest him particularly. As we made our adieus he said that he hoped we would communicate to him the findings gathered by the expedition. This morning we were presented to the Queen, who conversed with us for more than a quarter of an hour about the trip. Mathissen tells us that we are to be invited to dine at the royal table next Sunday. Before sailing we shall have to see their Majesties again to make our farewells, which would be all right if those eternal audiences did not necessitate all sorts of visits and return visits to and from the Lord-Marshal and other court hangers-on, which allow us barely enough time for the necessary purchases and scientific preparations. Making the former is not so easy as we thought it would be when we were still far from here. Our tent, with a lovely Danish flag, is almost finished; it is quite roomy so that the four of us can camp in it quite comfortably. Our beds are large bags made of two tremendous polar bear skins, covered outside with thick sealskins; they are so watertight that we will be able to camp most comfortably even in the snow. We have provided ourselves for the journey with warm greatcoats, which have long-haired sealskins on the outside and marten linings. However, the most necessary part of our wardrobe is a complete suit of oilskins, like those worn by sailors on shipboard as protec-

[5] BUNSEN, *Ann.*, **65**, 73 (1848).

[6] Carl Gustav (died 1847), Robert's elder brother, was *Regierungsrat;* Julius (died 1844) was *Amtsassesor.*

[7] Christian VIII (1786–1848), noted for his democratic principles.

tion against storm and rain. Our traveling boxes are twelve large oak chests covered with sealskin and bound with heavy iron clamps; they can be hung on the sides of the saddles of our pack horses. Since we shall travel for three weeks through a region that is totally uninhabited, we must take along a small portable cooking outfit and a large stock of provisions. On the advice of Icelanders we have met here, who know the country very well, we have decided to go from the geysers diagonally through the island past Hofsjökull [jökull = mountain covered with perpetual ice and snow, or a mass of eternal ice] to Myvatn [a lake] so as to avoid the rather dangerous crossing of the great glacial streams in the S.S.E. of the island.

We sail from here on May 1 on the "St. Croix," Captain Svenson, a brig of 12 or 24 guns in company with a naval detachment going to the Island of Greenland, etc., to protect the various Danish settlements. I hear that the departure of the little fleet of five or six war vessels will be the occasion of a large military marine display, during which the King will visit each ship and accompany it for some distance on the royal steamer. Our ship has a crew of 96, so that including us there will be exactly 100 men on board. Unfortunately she will cruise along the coasts of Greenland until our return, so that probably I will not be able to send you any word from Iceland, unless an unexpected opportunity arises. Perhaps we may even have to come back on another naval vessel....I embrace you all with my whole heart.

In true, unchangeable love,

Yours,

R. W. B.

We have just received the invitation to dine at the King's table and so now we have to pay our respects to the Crown Prince also.

II-*a*

April 27, 1846

Yesterday, just as I was taking the enclosed letter of the day before yesterday to the post myself, Sartorius sent a messenger in all haste after me to call me back, because the Chamberlain von Oxhölm had come in person to take us to the Crown Prince. On the way to the palace, he reported to us that the Crown Prince,[8] who has the reputation of being a rather queer fellow, had said to him that since an audience is a very boresome affair, he preferred to receive us in the Museum of Northern Antiquities that is housed in a wing of his palace. As soon as we arrived there, we were taken to the room of the Prince, who was standing by a table with a large box in his hand, and immediately, after we were presented to him, began to unpack the contents of the box and to explain the articles to us. Among these were lavas and ashes that he had recently received from the latest eruption of Hekla, which is still in action.[9] After we had looked at these and other curiosities, he suddenly turned to us with the remark, "Now, I will show you the museum; I myself will guide you around." At his request, we put aside all formality, and with our hats on and our overcoats around us, we went through the rooms of the collection, where he showed us several other things, and then turned us over to State Councillor Rafe, who is an acknowledged authority on northern antiquities. The prince meanwhile walked up and down, and when we made our adieus had an adjutant take us into the living room to see the gorgeous colossal oil painting of The Geyser.[10] When we got back to our quarters, we hardly had time to throw ourselves into our formal clothes to go to the royal dinner. About 40 were gathered in the reception room; all were in mufti. The King and Queen entered, he also in civilian clothes and no orders, and they conversed briefly with each of the guests and the courtiers. Both spoke in German at some length with us, and in so friendly and kindly a fashion that we were put quite at our ease. At the table, Sartorius and I sat opposite the King and Queen, between us the Court Marshall, who had led us to these places, whereas the most of the other guests seated themselves *pêle-mêle* as soon as Their Majesties had sat down. During the meal Their Majesties conversed a good deal with us about the Iceland expedition, and when the champagne was served, the King raised his glass and drank to our safe journey and to a speedy reunion in Copenhagen. After the coffee, we were asked to go to the King's cabinet, where the Queen and several of the court already were, and here the King himself showed us his collection of antiquities and explained the most notable items.

BUNSEN'S MOTHER

AUGUSTINE FRIEDERICKE BUNSEN, NEÉ GUNSELL
(1774–1853)

II-*b*

April 29

I have not yet been able to post this letter which, for safety's sake, I will not entrust to any one else. So I will add a few lines: the 27th we were invited to a large levee and evening concert where Montenegro of Paris sang, accompanied by all the court musicians. More than 400 ladies and gentlemen *en grande tenue* were present, the King in a gorgeous general's uniform, the Queen in a white satin dress strewn with brilliants. During the concert tea was served; later a variety of ices, refreshments, and fine wines, etc., were passed around by lackeys in red livery. The King and Crown Prince conversed at length with us, the latter for almost half an hour. With great enthusiasm he told of his trips to Iceland, and incidentally described a number of small traveling gadgets that he recommended to us, and which, as he said, he had thought out in his own little head. When we parted, he invited us to meet him the next morning so that he could show us the large palace, and for the evening he asked us to attend a meeting of the Society of Northern Antiquities, whose president he is. It was only nine o'clock yesterday morning when the Chamberlain Sea Captain von Ihringen came to take us to the Prince. He received us in his room, and accompanied by two adjutants and the castellan, His Highness, in person, guided us for one and one-half hours through the whole palace, from cellar and kitchen to the attic, on the way explaining to us the pictures and other objects of historical interest. When we reached the great ballroom, which is large enough to hold one of the local country palaces, he asked us to close our eyes, took us by the arm and led us to the

[8] He succeeded to the throne in 1848 as Frederick VIII.

[9] This series of eruptions, the 18th within historic times, began on September 2, 1845. The world learned of it when the ashes fell on the Orkneys.

[10] The Great Geyser. Its name, from the Icelandic *geysir* = gusher or rager, has now become the appellative for all gushing hot springs.

middle of the room, where at his command we again opened our eyes. He shook hands with each of us when we left and wishing us a pleasant trip, said: "I hope to see you gentlemen again on Hekla." So it is not impossible that we shall meet him in the autumn in Iceland, since he is sailing in the same fleet with us, going to Madeira, where he will await orders from the King as to whether he is to return through the high northern latitudes. In the evening at the Nordic Society he again came to us and, regretting that we were not sufficiently at home in Danish to follow the proceedings, he told us that he had asked several members to be our interpreters during the meeting. The proceedings, conducted by the Crown Prince himself, were quite lively, almost stormy, since there was a debate regarding a change in a society statute. The discussion was closed when the Prince proposed that the matter be left to a committee. During the election of a new member, the Prince himself opened the ballots and read out the names, employing with great ease, as he always did, the republican forms, which, as in almost all learned societies, are also used in this Nordic Society.

Tomorrow the King comes aboard our ship, where he will converse with us again. Probably our departure will be delayed until the 3rd. If the wind is favorable, as it has been up till now, we shall be in Iceland in nine days. In any case, the passage should not be longer than three weeks. Of course, you will hear from me from there, *if it is possible.*—I do not have time to read over these hasty lines, I send them to you with the request that you show them to nobody outside of our people in Cassel.

Yours,

R. W. B.

III

Copenhagen, May 2, 1846
7 P.M.

Dear beloved Mother:

I have just come off our ship, where we had taken our things, and am about to return on board because we shall sail tomorrow morning at four. I, therefore, have just time enough to send you a heartfelt farewell and, at the same time, dear mother, to inform you that our brig will be accompanied by another war brig also

From "Iceland, Its Volcanoes, Geysers and Glaciers," by Forbes, London, 1860

MT. HEKLA

ordered to Iceland so that you need have no fears at all about the safety of our passage. The day before yesterday we were on board when the King, accompanied by the Queen and the Crown Prince, inspected our brig. All were most gracious, as usual, and the King and Crown Prince examined the cabins fitted up for us, and on parting said a few friendly words as they shook hands with us. Everything promises well for our voyage and I anticipate the greatest success for our undertaking. I embrace all of you with my whole heart.

Yours,

R. W. B.

IV

Sunday, May 16, 1846
On board the St. Croix
5 A.M.

Yesterday evening at nine, my dearly beloved mother, we finally reached the goal of my most ardent wishes, and now are peacefully at anchor here, with the comfortable feeling of having behind us a good passage. Before us lies the capital, Reykjavik, that consists mostly of earth huts, and around us rises a glorious amphitheater of black mountainous masses, their tops covered with snow, and on them not a trace of vegetation to be seen. These nordic scenes are in fact cold and awe-inspiring, magnificent in their baroque and gigantic forms, but indescribably barren and monotonous in scenic details. However, no more, for the present, about this country, on which I have not yet even set foot. Only this, that yesterday our pilot told us that Hekla, which had been quiet for two months, began to be active again 14 days ago, and that the wonderful spectacle of the Geyser and Strokkr [the Churn, another well-known gusher, 100 paces from the Great Geyser] is beginning to burst forth in all its splendor. But now back to Copenhagen, so that you do not lose sight of me on the way. I wrote you a few lines just before I boarded our ship; this was, if I am not mistaken, at seven or eight o'clock on May 2. We hardly had time to get ourselves somewhat settled and to stow our luggage, before a violent storm broke. This raged throughout the night and came within a hair of postponing for several weeks our fine hopes of sailing. Our large anchor, yielding to the fury of the storm, broke in the middle, and before the second anchor, that was thrown out hastily, had a chance to catch hold, our brig grounded firmly on a shoal. It required strenuous efforts to get us afloat again, so that it was Monday, the 4th, before we ran out into the Sound in glorious weather but with the most contrary wind (N.W.). The fair weather held until Tuesday and then, to our joy, the wind shifted favorably to E.S.E., so that with an average speed of eight knots per watch, *i. e.*, eight sea miles in four hours, we flew through the Sound and the Kattegat, looking now right, now left, through the spyglass at the Swedish, Danish, and Norwegian coasts, and admiring the wonderful mirages that we saw continuously along the Swedish and Norwegian coasts. We saw these *fata morgana* most beautifully in all their nuances and oddities—truncated spires, inverted ships, rocks that floated free above the horizon, etc.—and, in addition, it was a beautiful sunny day, and not a trace of seasickness. Under such favorable auspices, by nine o'clock on Wednesday morning, the sixth day out, we had already passed Skagen [the northern tip of Jutland] and were sailing along briskly and gaily in the open North Sea toward the Orkney Islands. Soon after midday, the heavens darkened and the sun gave all indications that a storm was coming. About five in the afternoon, the wind was so strong that we were running with a speed of 11 miles in four hours, and about 6:30, a dreadful tempest broke—a storm in *optima formâ*. To see the awful spectacle in its full glory, Bergmann and I stayed on deck as long as the weather and our condition permitted. The movements of the ship, when it rose from the troughs of the waves to their mountainous peaks, were so precipitous and wild that the eye lost all sense of direction, and the sky, the waves, and the ship danced through each other in chaotic confusion. The roar of the storm and of the waves, that broke over the ship like a foaming surf; the hollow call of the megaphone accompanied by the shrill piping of the boatswain's whistle, to whose measures the sailors hanging onto the rigging and yards carried on their difficult task; the unearthly din of the things that were banging into each other and being thrown around—all this had about it something fiendish which can be thought of only with terror, despite the strong feeling of security that comes over you after a little reflection at such an instant, even in the face of impending danger. While the storm was at its height, a sailor fell 40 feet from the yard of the main mast and struck the deck right next to me. The poor soul was carried below unconscious, but has now improved enough so that his recovery can be hoped for. Three other sailors received less severe hurts; they were thrown to the deck by the violence of the ship's tossing—but accidents of this sort are inevitable at

such times if you do not hold fast every instant. Since the waves kept the deck constantly under water, we finally were forced to go to our cabin. But even here we did not escape the aroused elements; I had hardly thrown myself on my berth when a flood came down from the deck into our cabin, and covered the floor with three to four inches of water, so that our traveling bags and part of our clothes floated around and under our bunks in this water that sloshed from one side to the other. The next day the weather was glorious and calm, and the long, tremendous waves that set our ship into an almost threatening motion were the only remaining effects of the angry elements. On deck everything went on quietly. After such exertions, the sailors had a day off. Friday, the 8th, saw everyone busy with cleaning up and repairing the slight damages. Our ship's stores suffered considerably, so that everything had to be looked over, and renovated where necessary.

Saturday, the 9th. With excellent wind and weather we sailed through and between the Shetlands and the Orkneys. In the light of a beautiful sunset both groups of islands rose up from the sea in the jagged forms characteristic of these volcanic formations. On Sunday it stormed again so violently that services could not be held. Monday and Tuesday were the same, only more so. During this whole time, I was most miserably seasick. On the bright side, the storm blew us quite a bit forward. In the evening, a sailor captured an Iceland falcon that had lighted exhausted on our ship. The Faroes were far behind us and we were only 70 miles from the coast of Iceland. At noon on the 13th, we finally saw the western part of the south coast of Iceland in the most glorious weather, Suddenly, above the rising fog bank on the horizon, there appeared the snow-clad peaks of Reynar Drangar Jökull, with its splendid crater, and of the mighty Eyafjalla Jökull. This was a wonderful moment and gave us a foretaste of the Icelandic mountain world, in which the most imposing Alpine scenery is mixed in the most marvelous manner with the odd formations of the Auvergne volcanoes. On Thursday, the 14th, we were off the spurs of Mt. Hekla, and by evening we had reached the tip of Cape Reykjanes. If the wind had remained favorable, we could have been in Reykjavik that same evening or the following morning. However, once more a terrible storm came up. This wrapped us in fog and sleet, so that only with the greatest difficulty were we able to pass the small group of islands that came up out of the sea during a volcanic eruption at the beginning of this century. The weather continuously remained so foul that all sight of the coast was cut off, and the captain told us that we would have to cruise off the entrance of the harbor for several days before it would be possible to run in. However, the Fates had better things in store for us, because suddenly at 6 P.M. the sun broke through the clouds, and the panorama of the whole coast unfolded before our eyes. H. M. brig, the "Mercury," our faithful attendant, had been peacefully in the harbor for three hours. The cannon salute was omitted so that the quiet eider ducks on the Vidoe, the island to our left, would not be frightened from their nests, a consideration for which we gladly sacrificed the honor of a ceremonious greeting. In the evening, assisted by an excellent bowl of punch, we and all the officers of our vessel celebrated, in the captain's quarters, the end of our stormy but good voyage.

Not until 12 o'clock did we go up on deck again, where in this latitude it was still so light that the finest pencil writing can be read in the open air.—From all this you can see that our crossing, thought not without some discomforts, was still an exceedingly short one, because we covered this distance of 348 miles in 10 to 11 days, whereas on an average three to four weeks are usually allowed. I know you will be still more pleased when I also add that I am as well and chipper as a fish in water, and especially that I have lost all tendency to sniffle and catch cold.

I could have told you much more, but my time is limited by the sailing of the "Mercury" to Copenhagen; she leaves in a few hours for the Faroes, and so I send by her these hasty lines intended only for you and the Bunsens, and hope that they will be in your hands by the beginning of July.

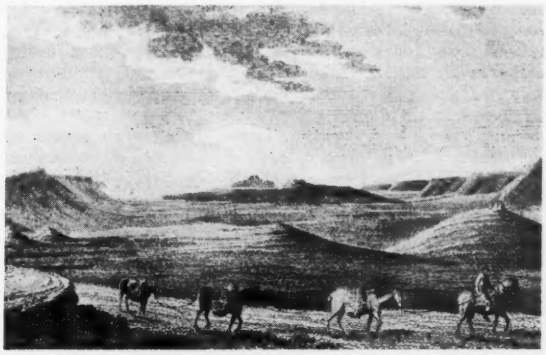
Yours,
R. W. Bunsen

V

Reykjavik, June 1, 1846

Dearly beloved Mother:

Yesterday Mr. Knutsen, one of the first Icelandic business men we met in Copenhagen, arrived here and offered to send this letter to Germany, by a ship that he is dispatching to Liverpool in a few days. I hope, therefore, that this second message from me will reach you safely as well as the letter that went by the "Mercury." We are still in Reykjavik, and living here at 64 degrees of latitude is not nearly so bad as I anticipated. My health remains of the best, and the exertions of the trip and the constant



From "Iceland, or the Journal of a residence in that island during the years 1814 and 1815," by E. Henderson, Edinburgh, 1818

MODE OF TRAVELING

living in the open air have agreed with me well, because I have never felt so fit and strong as now. Unfortunately our great trip to the Hekla geyser has to be postponed for 14 days, because the eruption has ceased for the past several weeks, and also our trip to the Northland, though we are very anxious to get on our way. Of course, we have plenty to do, since we still have to make a number of preparative observations here, and we must make a number of short excursions from here, during which we, at the same time, can accustom ourselves to the mode of traveling in use. The purchase of our pack and saddle horses proceeds very slowly because an epidemic broke out among the livestock as a consequence of the Hekla eruption, and the meadows are so devastated by the showers of ashes that the emaciated horses are not yet capable of long trips. So far we have only eight saddle horses and a like number of pack animals, while we need 25 to 30 for our trip. The day before yesterday we returned from a very profitable four-day excursion to the mud volcanoes and the sulfur mines of Krisuvik on the Reykjanes peninsula, where I made a rich haul for my special scientific purposes. The way there is wild and barren and in some places really terrifyingly beautiful. You ride where you can, following as much as possible the inlets of the sea, which are separated from each other by frightful lava flows, piled up in the wildest shapes, sometimes in clumps as high as a house, sometimes in masses that look like cold, stiff dough, covered with countless wrinkles, and shot through with many fissures and hollows. In front of the steep, jagged mountain chain, in which the fumaroles lie, there is one such lava flow that has the exceptional width of two miles. After we had gotten over this, not without considerable difficulty, we turned into the mountains, where a black volcanic sand smothers the last traces of a sparse growth of grass on the heights, and from there it is possible to look down on the two picturesque mountain lakes, between which the fumaroles issue from a steep mountain slope. This latter was our destination and we reached it after a half-hour's ride. In less than ten minutes our tent, with its beautiful banner fluttering in the wind, was standing next to the small steam craters which, roaring and hissing, whirled up mighty clouds of fume and drove them along the dark sides of the moun-

tains. Since these steam springs are one of the most important objects of my work, I left the arrangement of our small household to my companions and immediately set up my little laboratory. A fumarole that issued right next to our tent made an admirable steam bath, and later we also used it in the preparation of our simple meal. Not until midnight, when it was still so light that we could read the fine micrometer scales on our barometers, did we go to bed; we thoroughly enjoyed the agreeable warmth of our excellent sleeping bags and we did not crawl out again until the sun stood high in the heavens. It was the first warm sunny day that we have had here—no rain, or snow, or storm. In the sun the thermometer went to 20°C., and the wind blew the steam clouds away so nicely that I was able to finish almost all of my work by evening. I had reason not to regret my industry, because by sunset the blood-red sun, that set at 10:30, and the long narrow cloud streamers presaged the approaching storm, which kept us in our tent practically all of the next day. This, however, gave us a chance to test the quality of our traveling equipment. Our maximum thermometer showed that the temperature toward morning had not been above 2°, but we had felt no trace of this in our polar bear skins. It is difficult to realize the desolation and death-like quiet that prevails in this Icelandic mountain country. The only living things we met on this whole trip were a sea-gull that had lost its way and a pair of ptarmigan that flew up ahead of us; as far as the eye can see there is no tree or bush to cover the ground, which supports, in sorry fashion, occasional clumps of stunted heather and grass intermingled with lichens and mosses. Traveling in this mountainous wilderness is made much simpler by the fact that the picking of the path can be safely left to the little Icelandic horses. These intelligent beasts move so softly and sure-footedly, and yet make such good time, that without tiring it is possible to cover 10 to 15 miles, over a terrain that in Germany would be considered almost impassable. They are marvelously skilful in avoiding every stone while trotting, finding a passable spot, testing with their forefeet, where necessary, the solidity and safety of the ground before trusting their weight on it. However, they always trot or gallop whenever the nature of the ground permits. They are given neither oats nor bread, and live entirely on grass and hay; at times they do not refuse the half-dried codfish, stacked up in layers by the fishermen in the stony coastal inlets, but they take this only when vegetable fodder is not available.

Our life here in Reykjavik, when we get back from our excursions, is quite civilized and comfortable. One of Mr. Knutsen's factors has rented us for the summer, for 100 thalers, his small wooden house that was shipped from Copenhagen; we use this as our headquarters. His wife, a neat, clean, friendly housekeeper, looks after us at breakfast and noon, and supplies us with delicate ptarmigan and with fish cakes, which are wonderfully supplemented by the large tasty eider eggs. We shall soon have to abandon this mode of living, when we go into the interior of the island and are limited to our dry sea-biscuit and the cold provisions that we shall take with us. However, Mrs. von Matthiessen has provided for this emergency also, and has stocked our traveling larder with excellent bouillon tablets and, for holidays, even with several cans of hermetically sealed young vegetables. Our guides subsist almost entirely on raw, uncooked, dried, unsalted codfish, from which they tear off leather-like pieces, and devour these after spreading them with butter of the Icelandic variety, namely rancid, and showing a green and blue play of color.[11] Despite the terrible climate, these people sleep in the open wherever we pitch camp, or, if it is raining, they skilfully make for themselves for the night a kind of hut from our saddles and baggage, which they cover with the sealskin horse blankets and the strips of turf sod, which in this country are tied on to the horses instead of blankets [to keep the boxes from rubbing]. On our longer trip, in addition to four guides, we shall take along a Bessastadir[12] student, Thorlacius, who speaks Latin fluently, but who otherwise has no greater pretensions than our other guides. These students are in the Bessastadir school only during the winter, and obtain there a good theological and classical training. In the summer, they customarily go from house to house, to turn hay and to watch over the sheep and cows on the mountain slopes of their homes....In the intervals between our trips when we return here, there is no lack of diversions for the periods when we are not busy with our duties. In the evening, we often drink tea with Chamberlain von Hoppe, the bailiff or governor of the island, who does all he can to be at our service and help us in our plans. During the day we are often visited by the officers of our brig, which is cruising along the coast and comes into the harbor now and then. Captain Svenson is extremely friendly and obliging toward us. Yesterday we were at a splendid dinner on board, and we were called for by twelve sailors in his captain's gig. The officers received us on the starboard side and the watch paid us military honors. The sea was running so high that I did not feel very comfortable and hardly dared to accept the champagne. This is Confirmation Morning here in Reykjavik, and we shall have an opportunity to see the rich Icelandic national costumes. We have received invitations to a public ball to be held tomorrow, and the orchestra will include the whole police force, namely a fat, red-coated fellow, who plays the flute. I shall converse with the wife of the apothecary, who, except Mrs. Hoppe, is the only woman here who speaks French.

Mr. Knutsen has just sent to take my letter away, so I must close hastily. Keep well, my dear ones, and do not forget to send me a letter here.

R. W. B.

VI

Reykjavik, June 26, 1846

My dear beloved Mother:

The excellent condition of my health will be apparent to you when I tell you that I am writing these lines at 11:30 at night—incidentally in full daylight—having reached here only a very short time ago after a two-hour ride from the geysers of Reykir, where I spent three days. I can send you only a few hasty lines because on my arrival here I heard that a ship is leaving early tomorrow morning for Liverpool and will take my letter. Since my last letter to you, we have made the first long excursion of about eighty miles going as far as the Baula mountains, in part through entirely uninhabited parts of the island, and returned with much scientific booty and entirely satisfied with our results. On this trip, I personally was more fortunate than were my fellow travelers, whose work is far more dependent on the weather than is mine. The conditions under which we made this trip could not have been more unfavorable, as in two and one-half weeks we did not have a single day without heavy downpours, while the air temperature often was as low as 2° to 3°R. (32.5°–39°F.). On this occasion I cannot fully express my appreciation for the thoughtful foresight of Lieutenant v. Mathissen in so beautifully planning our traveling outfits to provide against all kinds of weather changes. We slept in our fine tent with our sleeping bags on the turf, or, if this was too damp, on our traveling boxes and saddles, or the few times it was possible, in the churches, where the altar served as both our dining and work-table.[13]

[11] "This kind of butter is prepared by freeing it of all its milk by repeated churning and washing; it is laid aside and first becomes mouldy and unsavory, then loses its yellow color and becomes white; in six months the butter would become completely rancid. Sour butter can be kept for 10–12 years without losing its goodness or first acidity. If sour butter is too old, it loses its acidity and weight, turns rancid and dries up." BARING-GOULD, "Iceland," Smith, Elder and Co., London, **1863**, p. 74.

[12] In Bessastadir, south of Reykjavik, there was a Latin school, the Schola Bessastadensis, in which selected students were prepared for the ministry. The school was moved back to Reykjavik in 1846. See BURTON, "Ultima Thule; or a summer in Iceland," Nimmo, London, **1875**, Vol. I, p. 155, for an account of Icelandic student life. At Bunsen's time, the students received a stipend of $33–$60 per annum.

[13] "To sleep in a church may seem somewhat sacrilegious; I ought therefore to mention that the churches, save in crossing the deserts, when tents are necessary, are the usual halting places throughout the island; and whenever the clergyman's domicile is full all strangers sleep there as a matter of course." FORBES, "Iceland; its volcanoes, geysers, and glaciers," John Murray, London, **1860**, p. 180.

Our party included 27 horses and five guides, with whom we had a rather unfortunate experience. Since our arrival, an epidemic of measles spread from a Danish ship over the island with incredible speed, so that in many of the larger settlements we found all of the 20 to 30 persons that made up the population down with this illness, and during the entire trip we had to deal almost entirely with people afflicted with measles or the itch. Right at the start both of our students broke out with measles, and eventually our two guides also. The latter made the entire journey with high fevers in the rain, and this despite the heavy work they had to do; and the former could only be persuaded to stay behind in a miserable peasant hut after the illness had already run about half its course. Only five days later they caught up with us, soaked clear to the waist, because they had ridden through rivers and marshes in order to overtake us while we were still at Reykholt. The young men are now entirely recovered and will make the trip with us to Geysir [The Geyser], Hekla, and Krafla [a volcano in N.E. part of the island]. We cannot start on this trip until the day after tomorrow, because we have not yet received assurance that we shall find enough grass for our horses on the way. Through lack of time, I shall unfortunately not be able to write anything about the trip itself, and probably I will not be able to do so until I am back in Copenhagen, because we shall spend the remaining part of our time in the interior of the island, where there are no means of communicating with the outside world. The scenery in this far north is full of desolation but is wonderfully beautiful and I shall never regret that I have seen it, even though it cost me the unbelievable privations and exertions to which we are subjected here, but under which I feel so strong and well that I can hardly wait until I am trotting toward the polar circle on my faithful little Icelandic pony.

Keep well, dear Mother. I embrace you and our dear ones with my whole heart.

With true love,

Yours,

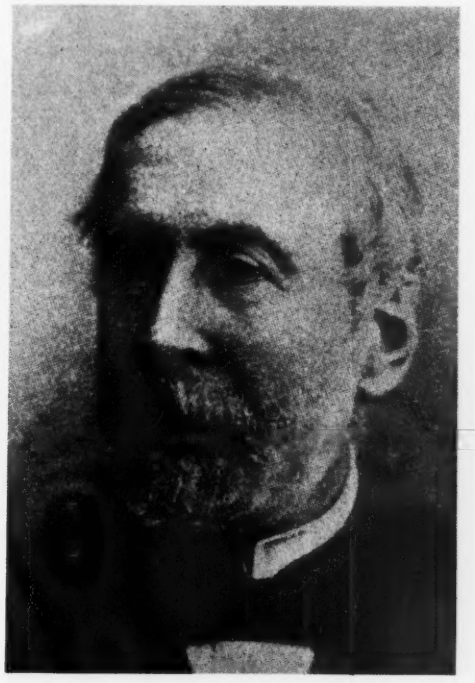
R. W. B.

VII

At the foot of Mt. Hekla
July 27, 1846

Dearly beloved Mother:

I hardly dare hope that you will receive these lines which I am sending, for possible forwarding to the governor of the island, by the messenger who is to take the stones we have collected here to Reykjavik. I am writing in the open air, in front of our tent far removed from all human habitation, in the greatest haste, because tomorrow morning at five we shall start on our journey to the Northland, and many preparations have still to be made for this eight-day trip through the totally uninhabited part of the island. We spent eight days at the geysers and ten here on Hekla and were so favored by the weather that we were able to finish our work very nicely. The spectacle of the geyser more than exceeded my expectations. We observed several eruptions there and found that the jet of water thirty feet in circumference rose to a height of 160 feet, while the steam of the boiling water jets whirled straight up 300 feet. I was extremely diligent there and have concluded a complete study of the mechanism of this wonderful gusher. The great outburst of Hekla ceased more than three months ago, so that it was possible for us to investigate at close range the still warm lava flow that is now covered with fumaroles, and the four craters that are still forming. I was more fortunate than my companions, and in the most beautiful weather, twice climbed to the top of the glacier that is covered with ashes that are still smoking, and from there I enjoyed in all of its beauty the magnificent spectacle of the northern sun going down and rising again in almost the same spot. I found there far more materials for my scientific purposes than I had anticipated, because the volcano, which only three months ago was raging furiously, has so far returned to quiescence that it is possible to climb down without danger through the thick cloud of fume to the floor of the great crater that is almost 300 feet deep. We have now seen the most beautiful parts of Iceland, and also have the most difficult parts of our work behind us, so that we can limit ourselves in the Northland to geognostic studies that involve few discomforts. Although my experiences here are fine and interesting, they are so offset by the great hardships and discomforts of traveling[14] that I am extremely anxious to return home. I am



ALFRED L. DES CLOIZEAUX (1817–97)
At the time of the expedition he was *repetiteur* at the École des Arts et Manufactures, Paris

bringing back a rich harvest, and best of all, a robust vigorous bodily health, such as I have hardly ever enjoyed before. In addition, this nomadic life, which literally contains nothing of European culture, has given me such a wild appearance that you would hardly recognize me with my long whiskers. Yesterday, friend Mathiesen sketched me on my horse. I am enclosing the sketch so that you can get an idea of my present appearance.

I expect to be back in Reykjavik in four weeks. It is very likely that we shall have to spend two weeks there to arrange our affairs. If our return voyage is favorable, you may expect word from me from Copenhagen as early as the beginning of October. However, do not count on this, as we may easily be more than four weeks on the return voyage because, if the Captain's orders permit, we shall probably spend some time on the Faroes. Until then you will have to do without any news from me, since from now on there is little possibility that a letter will reach Europe. I embrace you all with my whole heart, and sincerely hope that I shall find news from you in Reykjavik when I get back there.

Yours,

R. W. B.

VIII

On board the St. Croix
Sept. 7, 1846

Dearly beloved Mother:

We arrived safely here at the Faroes last night and were just busy anchoring off Thorshavn [the capital] when the welcome

[14] Compare WALTERSHAUSEN, *Göttinger Studien*, **1**, 323 (1847). "His scientific reputation attracts readers but he writes with a prodigious exaggeration on general subjects, and especially on scenery." BURTON, *op. cit.*, p. 244.

news came that in half an hour a ship would leave for Copenhagen, by which I can again give you news of myself before my arrival there, and also thank you for both of your valued letters that, to my inexpressible joy, I found waiting for me at Reykjavik. I am sorry that I shall not be able to send you more than a few words now, because the boat that is to take these lines to the departing ship is just about to put off.

BUNSEN IN ICELAND. PENCIL SKETCH BY MATHIESEN

Regarding the end of our land journey in Iceland, we extended our trip from Hekla almost to the Arctic Circle, and in the short space of several weeks traveled without an accident almost three hundred miles on our splendid little Icelandic horses. You will hear more of this remarkable trip as soon as I reach Copenhagen. At present, I will only tell you that we got back to Reykjavik on August 24th, in high spirits and with whole bones, and sailed from there on the 30th, without Waltershausen, who will remain a month longer in the Northland and then return to Europe by a merchant vessel. Our voyage here was again a most pleasant one. We sighted the Faroes as early as the 4th and had to cruise off the islands, that are almost continuously wrapped in fog, for three days before we could run into the harbor. It has not yet been definitely decided how long we shall remain here on the islands, but it is reasonably certain that our stay will not be more than fourteen days. If then our luck is as good as it has been, we can be in Copenhagen in eight to fourteen days from that time. I will do my utmost to finish up my business there as quickly as possible so that our reunion, so ardently longed for, may be held all the sooner....

With constant affection,
Yours,
R. W. B.

IX

Copenhagen, Sept. 17, 1846

Dearly beloved Mother:

When I wrote you a few hasty lines on the 7th from the Faroe Islands, at the time of my arrival, I had no reason to expect that I would be able to send you greetings from here only ten days later. While there we had continuous, adverse winds and such violent storms that we were confined to our island without being able to make any geognostic excursions, and I had become reconciled to the prospect of being rocked on the waves for at least three weeks before reaching the mainland. However, Providence wished it otherwise and so favored us that we made the 180 miles to Copenhagen in the unheard-of short time of four and one-half days, with the most glorious weather and with sails that were always full. I already wrote you that Waltershausen remained at the Arctic Circle to make certain observations there, and will return here in several weeks by a merchantman. We, on the other hand, hope to conclude our business here in eight days, since the court is now near Kiel, and thus we are spared a goodly number of levees and state visits. On the other hand, we shall certainly have to spend a few days at Kiel, in order to take leave of Their Majesties. We are rather obligated to do this as the King sent an order to our captain in Helsingör that if we wished to come to Kiel, he was to sail for that port at once.

I am busy arranging things and packing, so that I have to economize my time sharply, and can hardly hope to send you word from here again. On the other hand, I am all the more anxious to hear from you, my loved ones, and I request you to write me at *poste restante* at Kiel. I expect to be with you in not less than 14 days, and then I can give you an oral account of all that I now owe you because of the haste and superficiality of my short letters.

I embrace you all with my whole heart and until then I live in the joyful anticipation of an early, very delightful reunion.

With love as always,
Yours,
R. W. B.

IN RETROSPECT

The Boston Journal of Chemistry (1870) contained a column entitled "Atoms," made up of crisp, interesting items such as:

In Pennsylvania a sheet of iron has been rolled, 3 feet long and a foot wide, weighing but 3 ounces. It is thinner than common writing paper.

A Yankee paper mill has made a sheet of paper 25 miles long, 46 inches wide, and weighing 5 tons.

A Vermont marble company has sent a block of statuary marble to Italy.

Aluminium does not at present seem likely to become the familiar household metal that writers ten years ago predicted it would.

An anatomist who has discovered a new muscle in the human body has taken out a patent, and no one can use the muscle without paying royalty.

Some of the topics covered in the column on Familiar Science remind one of present-day "units" in general science:

How to bathe children
Where do diamonds come from?
Improved air furnaces
Shut your mouth (dust and disease)
Lightning rods
Leather in the teacup (the albumen in the milk uniting with the tannin in the tea to form enough leather in a year to make a pair of shoes!)
Metal pipes for conducting water
Silver in the sea
Chemistry of a hen's egg
Ice making in summer (ammonia refrigeration)

An Electrical Precipitator for Research and Demonstration Purposes

JOHN H. BILLMAN and R. VINCENT CASH

Indiana University, Bloomington, Indiana

AS EARLY as 1771, Beccaria (*1*) observed that aerosols might be precipitated by electrostatic means. The removal of suspended particles from a gas by means of electrical charges was suggested in 1824 by Hohlfeld (*2*) of Leipzig, who found that if he placed a charged wire in a jar filled with smoke, the smoke cleared rapidly, leaving a deposit on the sides and bottom of the jar. However, despite attempts by Lodge, Moeller, and others to utilize this observed phenomenon, it remained for F. G. Cottrell (*3*) to eliminate the main difficulties in the commercial application of the process which bears his name.

The general theory of electrical precipitation may be outlined as involving these steps: (*a*) the gas containing material to be removed is passed between a pair of electrodes known as the discharge and collecting electrodes; (*b*) the suspended particles are given a charge by means of electrons or gaseous ions from the negative discharge electrode; (*c*) the force of the electric field carries the charged particles to the positive collecting electrode; where (*d*) deposition of the charged particles and neutralization of their charges occur; and (*e*) the coagulated material is removed from the electrode to a suitable receptacle for subsequent disposal. In commercial work, intermittent unidirectional current and potentials from 30,000 to 90,000 volts are employed in electrical "treaters." Industrial installations have been made for purposes of: (*a*) recovering valuable materials suspended in gases; (*b*) cleaning, for discharge into the atmosphere, gases which are cause of public complaint on the basis of property damage or health menace; and (*c*) cleaning gases for use.

LABORATORY PRECIPITATORS

Whereas the development of electrical precipitators on a laboratory scale has generally preceded corresponding commercial installations, the construction of precipitators primarily for use in the research laboratory, in particular the organic laboratory, has not been very extensive. Elder and his co-workers (*4*) used a precipitator to collect the ozonides of terpenes. Copper foil wrapped around the outer surface of a water condenser jacket served as the collecting electrode. The inner electrode was fashioned from strips of galvanized window-screen wire. Drinker (*5*), in conducting his dust-in-air analyses, employed a precipitator consisting of a glass tube wound on the outside with metal foil or a spiral of copper wire, with a stiff wire in the center as the discharge electrode. His current was 110-volt alternating current, stepped-up to 15,000 volts by a transformer, but not rectified. Pestov (*6*) constructed a laboratory precipitator from a Fresenius cylinder which he used to condense liquid-in-gas suspensions such as phosphoric acid mists. In 1919, Lamb (*7*) worked out a portable Cottrell precipitator to be carried as a protection against war gases, and this in scale resembles a laboratory apparatus. He wrapped glass tubes with copper gauze as a collecting electrode; the discharge electrode was of two adjacent and parallel strands of fine copper wire mesh with numerous crosswise strands. A light storage battery and a "Perfex" induction coil supplied the necessary discharge voltage. Although this treater was effective with diphenychlorarsine smoke, it was not used in the first World War, and is probably too expensive to produce for its intended use.

Stone (*8*) recognized the need for a precipitator for lecture and classroom demonstrations. He suspended a stiff iron wire within a vertical length of two-inch iron pipe, both of which were connected to an induction coil, the latter being supplied current by a storage battery. Fumes and vapors introduced at the lower end were seen to cease coming out of the upper end when the current was applied. Realizing that the actual process was hidden from the observer by the pipe, he also suggested the use of a glass tube, moistened on the inner side with sulfuric acid, to give a conducting surface. This procedure seems troublesome and rather limits the demonstration to sulfuric acid mist. Ammonium chloride, which gives a white cloud, could be used with the pipe, although neither precipitator would stop the smoke produced by burning turpentine.

THE CONDENSER-PRECIPITATOR

The preparation of carbon suboxide by the pyrolysis of diacetyltartaric anhydride is accompanied by the formation of an acetic acid mist which must be removed before the suboxide is condensed. The inefficacy of water condensers (even when packed with glass beads) in the agglomeration of this acid fog led the authors to try electrical means. The modified Cottrell precipitator herein described completely removed the mist without entraining the carbon suboxide. A combined water condenser and electrical precipitator, this apparatus can be inexpensively assembled from materials readily available to the research worker or teacher, and is applicable for classroom demonstration as well as experimental purposes.

The condenser-precipitator (Figure 1) is constructed

from a regular water condenser with an outer jacket about 40 cm. in length. The collecting electrode is a piece of fine copper gauze, 38 cm. in length, and sufficiently wide to surround the inner tube with a slight

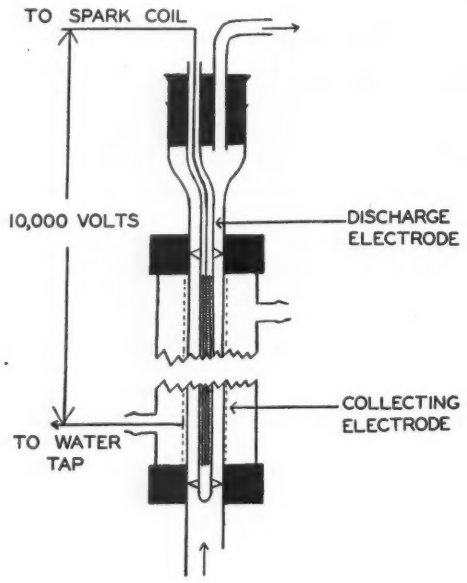


FIGURE 1

overlapping when placed in the water chamber of the condenser. This mesh electrode is bound to the inner tube with fine copper wire, a piece of which at the lower end leads through the inlet tube and the attached hose to the water tap, thus grounding the electrode. Water which is run through the outer jacket has its usual condensing effect, and may assist in the grounding, although the mesh and wire lead are essential.

The negative or discharge electrode consists of four superimposed sections of the fine copper screening, each 39 cm. long and three strands wide, bound together by winding with a strand from the mesh. The crosswise strands present many fine points for electrical discharge. This electrode is placed so as to extend down the geometric center of the inner tube and oppose the collecting electrode. In the original electrode, the lower extremity was wired to a small loop in the long end of an inverted T-shaped glass rod, the crosspiece of which rested in two notches in the tip of the inner tube. A bare copper wire, attached to the upper end of the electrode, was passed through one opening in a two-hole rubber stopper, and when pulled taut, was held so by a glass plug. Thus the electrode could be centered, but it was difficult to keep in place.

In an improved inner electrode (Figure 1), which appears to function as satisfactorily, the gauze strips are stiffened by insertion into 6-mm. glass tubing. This tube is sealed at the lower end and is suspended from the rubber stopper. Three small projections near either end hold the electrode sheath away from the condenser tube. There is, of course, a wire lead at the top. This latter electrode is more easily installed, is more truly aligned, and is not corroded by the material being treated. In either case, the inner electrode is twisted slightly to present points in all directions.

The source of potential is a Model T Ford spark coil, whose primary is operated by a storage battery. With a six-volt primary source, the secondary gives a maximum discharge of about 10,000 volts with optimum adjustment of the points of the coil. Doubling the primary electromotive force (to 12 volts) increases the discharge voltage to approximately 13,000 with occasional arcing at the points. These potentials were determined by measuring the maximum spark gap between opposing needle points. The higher voltage is slightly more effective for precipitation. The "hot wire" from the secondary of the induction coil is attached to the inner electrode of the precipitator. This wire must be carefully insulated from all sources of grounding. These unintended discharges as well as the electrode discharge can be detected readily by their coronas in the dark.

The precipitator described above works very effectively in coagulating the mentioned acetic acid mists. With the precipitator inactive, the dense white clouds stream through the condenser, but when the condenser-precipitator is operative, no vapors can be observed at the top of the apparatus.

This same precipitator might readily be used to demonstrate the phenomenon of electrical coagulation. The authors conducted the following demonstration. The familiar cigarette smoke was selected as the aerosol for treatment in view of its intimate appeal to the observer. The outlet tube at the top of the apparatus was connected to the side arm of an aspirator through which a current of compressed air was blown. The condenser was mounted on a very small suction flask. A glass tube holding a cigaret was connected to the side arm. When the cigaret was lighted, the automatic smoker inhaled the smoke, filling the condenser to the top. Switching on the precipitator caused the gray smoke to disappear in the upper regions of the condenser, but it reappeared when the electric current was stopped. By using a large mesh collecting electrode or one with small "windows" cut in it, the progress of the smoke up the tube could be observed. It is not necessary to have water running through the condenser when making such a demonstration. A six-volt primary E.M.F. is satisfactory for this purpose.

LITERATURE CITED

(1) BECCARIA, "Dell' elettricismo artificiale," Turin (1772).
(2) HOHLFELD, *Archiv. Naturl.*, Kastner, **2**, 200–7 (1824).
(3) COTTRELL, *J. Ind. Eng. Chem.*, **3**, 542 (1911).
(4) SPENCER, WEAVER, OBERRIGHT, SYKES, BARNEY, AND ELDER, *J. Org. Chem.*, **5**, 610 (1940).
(5) DRINKER AND THOMSON, *J. Ind. Hyg.*, **7**, 261 (1925); **14**, 364 (1932).
(6) PESTOV, *J. Chem. Ind.* (Moscow), **7**, 277 (1930); *Chem. Zentr.*, **II**, 448 (1930).
(7) LAMB, WENDT, AND WILSON, *Trans. Am. Electrochem. Soc.*, **35**, 357 (1919).
(8) STONE, J. CHEM. EDUC., **5**, 1001 (1928).

The Second Law of Thermodynamics

R. H. WRIGHT *University of New Brunswick, Fredericton, New Brunswick, Canada*

THERE can be little doubt that the Second Law of Thermodynamics is one of the major hurdles in the path of most students of physical and theoretical chemistry. Far too many undergraduates never perceive what the Second Law is or how it came to be formulated, even though they may acquire some facility in the use of thermodynamic formulas for solving routine problems. This regettable state of affairs is not surprising when one realizes how many textbooks of physical chemistry nowhere state the Second Law in forthright language, nowhere say "*this* is the Second Law: . . . ." Nor is the situation much improved (from the undergraduate's viewpoint) if the discussion is based from the outset on the rather sophisticated concept of entropy and the Second Law stated in terms of the increase of entropy in natural processes. This treatment is defensible on strictly logical grounds, but it has the defect of presenting thermodynamics as a completed edifice, and the student who can see how a structure came to be erected is in a far better position to enlarge it.

The following semihistorical exposition of the Second Law is offered in the hope that it will clear away some of these difficulties.

TEMPERATURE

The sense of touch leads to the conception of hot and cold bodies and to the idea of different degrees or states of hotness, but the gross senses are incapable of any very fine discrimination. A means of measuring this quality called hotness must therefore be devised. For this purpose, some property of a body must be discovered which changes in a continuous and tolerably uniform way with its state of hotness. Experiment shows that there are a number of such properties—electrical resistivity, volume, etc. Hotness may therefore be measured in terms of some other measurable property of matter.

Measured hotness is called temperature. The mercury-in-glass thermometer measures hotness or registers temperatures in terms of volume changes using degrees of arbitrary size. Charles and later Gay-Lussac investigated the thermal expansion of gases measuring temperatures with the mercury thermometer, and enunciated a generalization known as Charles' Law or Gay-Lussac's Law. Later on, because of the very regular expansion of many gases, the gas thermometer replaced the mercury thermometer as the standard reference instrument and the temperature scale was defined in terms of gaseous pressures or volumes. When this was done, Charles' or Gay Lussac's Law ceased to be a generalization and became a truism, and this was the position until Lord Kelvin showed that a scale coinciding with the perfect or ideal gas scale could be derived independently of any particular kind of matter.

These preliminary remarks on the concept of temperature and the thermometric scale are essential to an understanding of the way the Second Law grew up, and until the Kelvin scale is derived it will be understood that all temperatures mentioned are defined ultimately in terms of the gas scale.

HEAT

When the two bodies which are at different temperatures are brought together, it is generally observed that their temperatures change in such a way as eventually to become equal. From this we infer that something has passed from one body to the other. This "something" is not temperature, for the change in temperature of one body is not generally the same as the change in temperature of the other. We call this something heat.

If, in order to measure heat, we take as a unit that quantity of the "something" which is required to raise the temperature of one gram of water one Centigrade degree, than the quantity of heat lost by the hotter body and gained by the colder body can be measured. It is found that the two quantities are equal. While we have defined a unit in which quantities of heat may be measured and expressed, we have made no suggestion as to the nature of the thing called "heat." So far it is simply something whose entry into or withdrawal from a system at constant volume will cause its temperature to change, provided no new phase appears during the addition and the relative masses of the phases already present are unaltered.

THE FIRST LAW

The First Law of Thermodynamics is a generalization of the observed proportionality between heat and the various forms of energy—kinetic, potential, electrical, and so forth. Regarding heat as a form of energy, the First Law states that energy must be conserved in all processes, providing only that there is no alteration in mass. From the First Law in this general form, various laws (for example, those relating to thermochemistry) may be deduced.

But while the First Law prescribes certain conditions which must be fulfilled *if* a process should occur, it has nothing to say about whether that process will in fact take place. The First Law is, of course, not unique in this. All the laws of physical and chemical science with one exception are similar: they begin with the word "whenever" and go on to describe what happens afterward. They take the "when" for granted and are silent about the "whether." The only law that enables us to predict whether or not a process which is

otherwise possible can actually be expected to occur is the Second Law of Thermodynamics. It is for this reason that the Second Law is of central importance in practical and theoretical physics and chemistry.

It should be noted, however, that the Second Law has nothing to say about the speed with which expected changes will take place, so that many processes that are "thermodynamically possible" are not actually observed, presumably because they are excessively slow.

THE TRANSFORMATION OF HEAT INTO WORK

The steam engine, invented during the eighteenth century, is essentially a device for converting the heat derived from the combustion of coal into mechanical energy. At the time of its invention, however, neither the concept of heat nor the concept of energy had been clearly defined in the modern way. Joule, besides measuring the mechanical equivalent of heat, had also to convince people that there was such a thing to measure. But with the gradual acceptance of the hypothesis that heat is a manifestation of energy, and with the recognition of the steam engine as a machine for converting heat into other forms of energy, attention came to be focused on the conditions necessary for the conversion.

It was very soon realized that mechanical and other kinds of energy can be obtained from heat in two kinds of processes: cyclic and non-cyclic.

For example, a compressed gas may be allowed to expand and lift a weight. It is observed that under these conditions the gas tends to cool and heat passes into it from the surroundings. If the gas expands without raising the weight (free expansion) there is no cooling and no heat absorption. Hence the heat absorbed is converted into mechanical work in raising the weight. This is a non-cyclic process for converting heat into work.

In the steam engine the conversion takes place in a cyclic process. Water absorbs heat from a furnace and is converted into steam. The steam passes into a cylinder where it expands and does work. On the return stroke of the piston, the expanded steam passes into a condenser where it becomes liquid water again, and the water then goes back into the boiler. At the end of the cycle all parts of the machine—water, piston, etc.—have returned to their initial states and can repeat the cycle over and over again, and during each cycle heat absorbed from the furnace is taken out of the machine as mechanical work.

Obviously from the practical standpoint of running an industry, devices which convert heat into work cyclically (we shall call such devices heat engines) are more useful than non-cyclic devices. As soon as we recognize the true nature of heat engines it becomes a matter of practical importance to scrutinize their operation in order that they may be properly designed so as to produce the maximum amount of mechanical work from a given quantity of heat.

Examination of a large number of cyclic processes discloses the fact that in no case is *all* the heat which enters the machine converted into other kinds of energy: at some stage of the cycle there is a liberation of heat by the machine. For example, in the steam engine the exhaust steam gives up in the condenser some of the heat it absorbed in the boiler. The work which the machine performs is, of course, equivalent to the difference between the heat absorbed and the heat rejected, in accordance with the requirements of the First Law.

It now becomes important to ask whether this incomplete conversion of the heat supplied to the engine is due to faulty design or whether it is inherent in the operation of the machine. We will begin the enquiry by considering what conditions are necessary for obtaining the maximum amount of work from a process. Having discovered what these conditions are we can imagine various cycles to be carried out in the proper manner to yield the greatest net amount of work. If we find that even under these ideal conditions it is impossible to devise a cycle that will transform into work *all* the heat put into it, then we must conclude that we are dealing with something which is inherent in the operation of heat engines. It is obviously beyond the scope of this discussion to examine in this way every cycle that has ever been used or proposed for use in a heat engine. We will therefore examine only one, the Carnot cycle for an ideal gas, and then assert as a verifiable fact that similar analyses of all other cycles lead to the same conclusion.

THE CONCEPTS OF MAXIMUM WORK AND REVERSIBLE PROCESS

In the course of thermodynamic reasoning it is from time to time necessary to imagine the existence of certain ideal pieces of apparatus: frictionless pistons, vessels whose walls are perfect non-conductors of heat, semipermeable membranes, etc. It is legitimate to postulate such non-existent apparatus because it is possible to construct devices approximating to them, and because their realization would violate no law of nature except the well-known Law of the Perversity of Inanimate Objects. It would not be legitimate to imagine a device which could not even be approximated and whose operation would be contrary to any well established generalization.

When a gas expands in a cylinder fitted with a frictionless piston, the work obtained from the expansion depends altogether on the force which *opposes* the expansion. In the extreme case, when the opposing force is zero, we have free expansion and no work performed by the gas. In order to obtain the maximum amount of external work from an expansion, the external pressure must be at all times only infinitesimally less than the pressure of the gas itself. Similar conditions hold for other types of process. In general, in order to obtain the maximum amount of work from any process it is necessary that the force which opposes

the process should differ only infinitesimally from the force producing it. Under these conditions the process is said to be taking place reversibly, because it will be reversed by an infinitesimal increase in the opposing force.

In everyday language, reversible means merely "capable of being reversed"; in thermodynamics the word has a special, technical meaning because of the requirement that the reversal shall follow an *infinitesimal* change in the environment.

In order that a process may be reversible, it is necessary that (1) at all stages the system must be in frictionless mechanical equilibrium with the external forces (or only infinitesimally removed from such equilibrium), (2) the moving parts must have infinitesimal momentum in order that their motion may be reversed by an infinitesimal change in the conditions, (3) wherever there is thermal contact, either within the system or between the system and its environment, the temperature must be the same or only infinitesimally different. These conditions are secured and a process made thermodynamically reversible if it is frictionless and infinitely slow. Put in another way, a change is reversible if it proceed through a continuous sequence of states which are only infinitesimally removed from equilibrium. Reversibility is therefore an ideal which though unattainable can be more or less closely approximated. It follows from the nature of a reversible process as here defined, that the work obtained from an irreversible process will be less than the maximum.

THE REVERSIBLE CARNOT CYCLE FOR A PERFECT GAS

A Carnot cycle is a particular kind of cycle in which some substance, called the working substance, undergoes a series of alternate isothermal and adiabatic changes which result in the conversion of heat into work. Any substance may be put through a Carnot cycle, but the usual example worked out in textbooks assumes that the working substance is a perfect gas. The analysis of the operation of this cycle is too well known to be repeated here. It involves an evaluation of the heat and work terms accompanying each stage of the cycle, and the equating of the sum of the heat terms with the sum of the work terms in accordance with the First Law. This leads to the formula:

$$\frac{Q_1 + Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}$$

where Q_1 is the heat absorbed at the higher temperature T_1, and Q_2 the heat absorbed at the lower temperature T_2. At T_1, Q_1 is a positive number, heat entering the gas; at T_2, Q_2 is a negative number because the gas gives up heat to the surroundings.

The efficiency of a heat engine is defined as the ratio of the heat converted into work to the heat supplied to the machine. Denoting efficiency by η, then the efficiency of the Carnot cycle for a perfect gas is, by definition,

$$\eta = \frac{Q_1 + Q_2}{Q_1}$$

Combining this with the preceding formula, we have

$$\eta = \frac{T_1 - T_2}{T_1}$$

This means that when a perfect gas is put through a reversible Carnot cycle, the work obtained from the cycle is always less than the heat supplied to the machine at the higher temperature, unless the lower temperature is the absolute zero, which has not yet been reached. It will be noticed that the temperature T_2 at which the machine rejected the unconverted heat was lower than T_1.

THE SECOND LAW OF THERMODYNAMICS

Since a similar analysis of the operation of all other cyclic processes leads to a similar conclusion, we are forced to conclude that the incomplete conversion of heat into work in heat engines is an inherent rather than an accidental property. This result may be stated in the form of a generalization, and this generalization is the Second Law of Thermodynamics:

No heat engine can be constructed which will convert all the heat supplied to it into other forms of energy; some part of the heat supplied is invariably given out by the machine at some temperature lower than that at which the heat supplied was taken in.

A heat engine is any device which takes in a supply of heat, goes through a cycle of operations resulting in the performance of work, and at the end of the cycle returns to its original condition so that no work has been obtained save at the expense of heat supplied to the machine.

The statement of the Second Law given above may be shortened to: *The production of work by a cyclic process is always accompanied by the absorption of heat at a higher temperature and the ejection of heat at a lower temperature.* Put in this way, it is easy to see how the Law applies to refrigerating machines, which are heat engines driven backward by some external agency. For heat engines running in reverse, the Second Law applies "in reverse" also: *The absorption of heat at a lower temperature and the ejection of heat at a higher temperature by a cyclic process is always accompanied by the absorption of work.*

It will be seen that the Second Law denies the possibility of constructing a machine for the continuous production of work at the expense of heat drawn from surroundings at a temperature lower than that of the machine itself. The existence of such a machine would not contravene the Law of Energy Conservation, and so it is apparent that the Second Law sets forth a restriction upon the applicability of the First Law. Thus it is found that a given quantity of work may always be completely converted into the equivalent quantity of heat, but the converse is not necessarily true. It is the function of the Second Law to define this one-sided convertibility.

It must be remarked that the Second Law applies only to systems containing large numbers of molecules

because it is meaningless to speak of the temperature of a single molecule or small number of molecules.

CARNOT'S THEOREM

The Second Law as stated in the preceding section is qualitative since it merely requires that only a part of the heat supplied to a heat engine shall be converted into other forms of energy. To obtain a quantitative statement, we must answer the question, "What part?" A proposition known as Carnot's Theorem provides the answer. It states that (1) for given temperature limits, all reversible cycles have the same efficiency, and (2) for given temperature limits, the efficiency of a reversible cycle cannot be exceeded. In a preceding section, the efficiency of a particular reversible cycle (the Carnot cycle for a perfect gas) was found to be related to the temperatures between which it operated as follows:

$$\eta = \frac{T_1 - T_2}{T_1}$$

Carnot's Theorem enables the same formula to be used and the same efficiency assigned to *any* reversible cycle operating between the temperatures T_1 and T_2, and so provides the required quantitative result.

This theorem is established by the method of *reductio ad absurdum*, that is, by showing that any other assumption would lead to consequences at variance with the Second Law as stated above. Thus we imagine our reversible Carnot engine to be driven backward by any other engine. If the other engine is more efficient than the Carnot engine, then the compound engine will raise heat from a low to a high temperature without benefit of energy supplied from outside, and will, on the contrary, produce work at the expense of heat taken from the low-temperature source. As this is contrary to the Second Law the other engine cannot be more efficient than the Carnot engine. Again, if we imagine our Carnot engine to drive backward any other reversible engine we can show that the Carnot engine is not more efficient than the reversible engine it is driving, and since it is not less efficient the efficiencies must be equal. It follows, too, from the concept of thermodynamic reversibility that irreversible engines are less efficient than reversible ones.

THE KELVIN SCALE OF TEMPERATURE

The choice of the ideal gas thermometer as the standard had the effect of making Charles' Law a truism. The Second Law leads to a temperature scale which coincides with the gas scale and which is independent of the properties of any particular kind of matter. In the discussion of the Carnot cycle for a perfect gas the temperatures T_1 and T_2 were gas thermometer temperatures. It was shown that for any reversible heat engine working between T_1 and T_2,

$$\frac{Q_1 + Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}$$

so that,

$$\frac{Q_1}{Q_2} = -\frac{T_1}{T_2}$$

(The minus sign need cause no difficulty because Q_1 and Q_2 are heats "absorbed" and Q_2 is numerically negative when heat is ejected at T_2.)

Thus the ratio of two temperatures on the ideal gas scale is equal to the ratio of the heats absorbed and ejected by any reversible heat engine working between those two temperatures. Any reversible heat engine may therefore be used in principle as a thermometer if we measure the heats which it absorbs and rejects. This has the effect of divorcing the temperature scale from the properties of an ideal gas and restores to Charles' Law the status of a generalization.

The thermodynamic scale has an absolute zero coinciding with the zero of the gas scale for, if T_2 becomes zero the efficiency of the heat engine becomes unity, and an efficiency greater than one is ruled out by the First Law.

CLAUSIUS' THEOREM

The quantitative deduction from the Second Law, which Carnot's Theorem provides, covers the case of a reversible heat engine taking in heat from a reservoir at one fixed temperature and giving out heat to a second heat reservoir at a second fixed temperature. This restriction to two fixed temperatures can be removed by deducing a further proposition known as Clausius' Theorem which turns out to have very far-reaching implications.

To prove this theorem we show that the changes accompanying any reversible cycle may be duplicated by imagining a sufficient number of infinitesimal Carnot cycles having their infinitesimal isothermal parts everywhere close to the actual path of the original cycle. (An infinitesimal Carnot cycle is one whose *isothermal* parts are infinitesimal.) Since, for each of the Carnot cycles,

$$\frac{Q_1}{T_1} + \frac{Q_2}{T_2} = 0$$

it follows that for all the Carnot cycles,

$$\sum \frac{Q}{T} = 0$$

and for the original cycle,

$$\oint \frac{Q}{T} = 0$$

where $\oint$ signifies the integral around the complete cycle.

The statement that, for any reversible cycle,

$$\oint \frac{Q}{T} = 0$$

is known as Clausius' Theorem.

ENTROPY

Clausius' Theorem owes its importance to the fact that the concept of entropy follows directly from it. It can be shown simply as a mathematical proposition that if we have a function (x) such that,

$$\oint (x) = 0$$

then

$$\int_A^B (x) = \text{a constant}$$

and the value of the constant depends only on the limits of integration A and B, and is independent of the way in which (x) varies in between. The physical meaning of this is that (x) is some property of a system which depends only on its immediate state and not at all on how it arrived in that state. Pressure, volume, temperature, internal energy, are all properties of this sort. If we put the value of Q/T for any infinitesimal reversible process equal to ds, then Clausius' Theorem can be written,

$$\oint ds = 0$$

and hence

$$\int_b^a ds = \Delta s = s_b - s_a$$

Thus the mathematical development of the Second Law has led to the discovery of a fundamental property of any system which is called its entropy and is denoted by s. The entropy ranks with the temperature or internal energy as one of the more important variables of any system. Just as the absolute value of the internal energy cannot be determined but only changes in it, so also the absolute value of the entropy is indeterminate although changes in the entropy can be arrived at, and in a comparatively simple way.

(Absolute values of the entropy can be determined with the help of the Nernst Heat Theorem or Third Law of Thermodynamics it is true, but we are only concerned here with what can be done with the first two laws.) To find the change in entropy of a system during some transformation, we have only to imagine some reversible path by which the system could be taken from the same initial to the same final state, and for that path evaluate

$$\int \frac{Q}{T}$$

The units in which such changes in entropy are expressed have the dimensions of energy divided by temperature, usually calories per degree.

THE MOST GENERAL FORM OF THE SECOND LAW

In the preceding section we showed how the change in entropy of a system may be calculated during any process. Unless the system happens to be completely isolated, a change in entropy of a system will be accompanied by a change in the entropy of its environment. When we ask ourselves how the entropy of the system-plus-environment changes during reversible and irreversible processes we arrive at an answer which embodies the Second Law in its most general form.

It is easy to show that when a reversible change takes place in a system the change in entropy of the environment is equal in magnitude and opposite in sign to the change in entropy of the system. Denoting entropies of system and environment by s and s', respectively, and entropies of system-plus-environment by S, then for any reversible infinitesimal process,

$$dS = ds + ds' = 0$$

It is not so easy to see how the entropy of system-plus-environment varies as a result of irreversible changes originating in the system, and as the problem is seldom adequately treated in textbooks it will be examined in some detail here. Consider a system which as a result of some irreversible process taking place within it absorbs an amount of heat Q' from surroundings at a uniform temperature T'. (The environment is assumed to be at a uniform temperature so that it will not undergo any changes except as a result of something happening in the system.) Because the environment is at a uniform temperature, any heat entering or leaving it does so because of a temperature gradient existing in the system. In such a temperature gradient, the parts of the system immediately adjacent to the environment will be at a temperature only infinitesimally different from that of the environment, and therefore any heat which enters or leaves the environment does so reversibly. Hence the change in entropy of the environment due to absorption of heat Q' by the system is,

$$ds' = -\frac{Q'}{T'}$$

The change in entropy of the system is found by supposing the system to undergo the same process by a reversible path wherein it absorbs heat Q and is at a temperature T, and the change in entropy is

$$ds = \frac{Q}{T}$$

Now, whether the process be reversible or not, the First Law requires that

$$dU = Q - W$$

so that

$Q' = dU + W' =$ heat absorbed by system during the irreversible change

and

$Q = dU + W =$ heat absorbed by system during the equivalent reversible change.

The entropy changes of system and environment are, then,

$$ds = \frac{dU + W}{T} \text{ (system)}$$

$$ds' = -\frac{dU + W'}{T'} \text{ (environment)}$$

The change in entropy of system-plus-environment is the sum of these, or,

$$dS = \frac{T'(dU + W) - T(dU + W')}{TT'}$$

Now, because the process is irreversible, $W > W'$ and therefore $(dU + W) > (dU + W')$. This may

mean that $(dU + W)$ is a numerically larger positive number than $(dU + W')$ or that it is a numerically smaller negative number. If they are positive the system is actually withdrawing heat from the surroundings and therefore T' must be greater than T. Conversely, if $(dU + W)$ and $(dU + W')$ are negative numbers, T must be greater than T'. The effect of these inequalities is to make

$$T'(dU + W) - T(dU + W')$$

a positive quantity under all circumstances. This leads to the conclusion that the entropy of system-plus-environment is invariably increased by the occurrence of an irreversible process.

Summarizing these conclusions, for system-plus-environment (or for an isolated system),

$$dS = 0 \text{ for reversible processes}$$

and

$$dS > 0 \text{ for irreversible processes}$$

This is the most general and the most profoundly important consequence of the Second Law. Indeed, it is often *called* the Second Law. This is, however, scarcely desirable because the statement that $dS \geq 0$ is scarcely a direct generalization from observation, but rather the logical consequence of such a generalization. It has been said that "we cannot get more out of the mathematical mill than we put into it, though we may get it in a form infinitely more useful for our purpose." This being so, the statement that $dS \geq 0$ is implicit in our statement of the Second Law, and vice versa. When thermodynamics is being developed merely as a logical system, considerable economy of space can be achieved by starting with the Second Law in this more abstract form. But its experimental basis is thereby obscured, and the intellectual hurdle right at the start is too much for many beginners. Also, the treatment given here indicates approximately the way the Second Law actually came to be formulated.

WHAT IS ENTROPY?

Insofar as a pure mechanical use of the entropy function in solving problems is concerned, the question of what entropy is does not need to be answered. Nevertheless, it is desirable that the question be considered because beginners, accustomed to conservation laws of mass and energy, are often bewildered by a quantity which is far from being conserved and grows ever larger.

It will be remembered that while a given quantity of work may always be completely converted into heat, the converse is not necessarily true. The one-way increase in entropy in natural, irreversible processes is merely a generalization of this one-sided convertibility of work and heat. The kinetic theory regards heat energy as residing in the unordered motion of molecules. On the other hand, those other forms of energy which are called work are obtainable only when molecules possess some orderly motion or arrangement, giving rise to kinetic or potential energy. The transformation of work into heat therefore involves a change from ordered motion or arrangement to the disorderly motion and chaotic arrangement known as thermal agitation. It is not difficult to see in a general way that the change from order to disorder should take place naturally and spontaneously while the converse should not.

Boltzmann approached the problem from this viewpoint and was able to show that the entropy of a given system was a function of its probability, such that the greater the entropy the greater is the probability. Thus changes which increase the entropy of the world involve a change from a molecular arrangement of smaller probability to one of greater probability.

According to A. S. Eddington, "the practical measure of the random element which can increase in the universe but can never decrease is called entropy."

THE IMPORTANCE OF ENTROPY TO CHEMISTRY

Theoretical chemistry if reduced to its simplest terms sets out to answer three questions. Given a certain combination of materials under given conditions of temperature, pressure, etc., we may ask: (1) Will these substances react, and if so what products will be formed? (2) How far will the reaction go; that is, what will be the condition of equilibrium which terminates the reaction? (3) How quickly will this state of equilibrium be reached? Thermodynamics, through the concept of entropy, provides, at least in principle, a complete answer to the first two of these questions. It has, however, nothing whatever to say about the third, which must be answered in terms of the kinetic and quantum theories.

The way thermodynamics answers the first question can be seen from the following considerations. All natural processes are irreversible. Every natural process therefore results in an increase in the entropy of the world. Put in another way, the only processes which have ever been observed to take place are those which result in an increase in the entropy of the world. Given a description of some particular system we imagine various small changes to take place in it and calculate the resulting change in entropy of system-plus-environment, and the Second Law tells us that only those changes which entail an increase in the entropy of the world can be expected to occur.

In order to answer the second question, we remember that the entropy of the world is unaltered by a reversible process, and that for a process to be reversible the system must be in equilibrium or only infinitesimally removed from it. Hence, in order to find the equilibrium conditions in any reaction, we have only to find what conditions are necessary in order that, for any infinitesimal change, $dS = 0$.

The increase in the entropy of the world during natural processes has an important philosophical consequence which is developed at some length by A. S. Eddington in his book, "The Nature of the Physical World." Given two instantaneous pictures of the

Universe, there is only one law of nature which would enable us to decide which was taken first: the later picture is the one in which the entropy is greater. Eddington uses the phrase "time's arrow" to express this one-way property of time which enters the conceptual scheme called Science through the Second Law of Thermodynamics only.

We cannot do better than close this account of the Second Law with the following quotation from Eddington's book.

"I wish I could convey to you the amazing power of this conception of entropy in scientific research. From the property that entropy must always increase, practical methods of measuring it have been found. The chain of deductions from this simple law have been almost illimitable; and it has been equally successful in connection with the most recondite problems of theoretical physics and the practical tasks of the engineer. Its special feature is that the conclusions drawn are independent of the nature of the microscopical processes that are going on. It is not concerned with the nature of the individual; it is interested in him only as a component of a crowd. Therefore the method is applicable in fields of research where our ignorance has scarcely begun to lift, and we have no hesitation in applying it to problems of the quantum theory, although the mechanism of the individual quantum process is unknown and at present unimaginable."[1]

[1] EDDINGTON, "The nature of the physical world," 1st ed., The Macmillan Co., Inc., New York City; Cambridge University Press, Cambridge, England, **1928**, p. 75.

SOME LECTURE EXPERIMENTS USING RUBBER BALLOONS

EDWIN T. MITCHELL

Holy Cross College, Worcester, Massachusetts

IN DEMONSTRATING before a large class in general chemistry, many principles can be illustrated very clearly by using reactions which evolve gaseous products. Such reactions can be shown by attaching a rubber balloon to the reaction flask and noting the relative rates at which the balloons are inflated. This idea was used by Walton[1] to show the relative strengths of acids. Balloons have also been used very successfully by the author in demonstrating the following principles.

(1) LAW OF MASS ACTION

The common method of demonstrating this fundamental law is to employ either the iodine clock reaction or the arsenious sulfide clock reaction. A much simpler method of demonstrating this law, however, can be carried out as follows:

Fit four 125-cc. Erlenmeyer flasks with one-hole rubber stoppers into which is inserted a short piece (two inches) of glass tubing, flared at the outer end. Over each flared end is pushed the mouth of a balloon. The balloons can be fixed to the glass tube in a more permanent fashion by making them tight with a piece of string or a rubber band.

To carry out the experiment, add to the four flasks 50 cc. of hydrochloric acid of the following concentrations: 6 *M*, 3 *M*, 1.8 *M*, and 1 *M*, respectively. Through the mouth of each balloon pour two grams of 20-mesh granular zinc. Next insert into the mouth of each flask one of the stoppers, to which a balloon is attached. The balloons are then raised so that the zinc is allowed to fall into the acid solutions. The hydrogen generated fills the first balloon immediately, the second in approximately a minute and a half, the third in about four to five minutes, and the fourth only after a period of a half an hour.

[1] WALTON, "Lecture demonstrations in general chemistry," J. CHEM. EDUC., **8**, 303 (1931).

(2) COMMON ION EFFECT

This experiment shows the manner in which an excess of acetate ions decreases the acidity of the acetic acid.

To each of two 125-cc. Erlenmeyer flasks fitted with stoppers, carrying balloons as described above, are added four grams of calcium carbonate. To one of the flasks 50 cc. of water are added and to the other 50 cc. of a saturated solution of sodium acetate. The solutions are shaken and allowed to settle. To each flask are added 15 cc. of 1.5 *M* acetic acid. Immediately insert the prepared stoppers in the mouths of the flasks.

The repression of the hydrogen ion is very strikingly shown by the very slow evolution of carbon dioxide, thus giving rise to a slow inflation of the balloon as compared with the rapid evolution of carbon dioxide in the other flask and the consequent rapid inflation of that balloon.

If the experiment is carried out as described very little frothing of the solutions occurs.

(3) CATALYSIS

To each of two 125-cc. Erlenmeyer flasks are added 50 cc. of 1 *M* sulfuric acid. For this experiment, as for the others, one-hole rubber stoppers should be available which have been fitted to balloons by means of glass tubes.

Into each of the balloons are poured two grams of 20-mesh granular zinc. To one of the flasks containing the acid is added about a gram of copper filings. The stoppers are put on the flasks and the balloons held up so that the zinc is allowed to fall into the acid solutions. The solution containing the copper filings evolves hydrogen much more rapidly than the other solution. When the zinc is all used up, the copper filings can be taken out and shown to the class. Platinum foil can also be used in place of copper.[2]

[2] *Note:* The zinc must be in contact with the copper filings or platinum foil.

Capillary Pipets

H. A. FREDIANI *Fisher Scientific Company, Pittsburgh, Pennsylvania*
L. GAMBLE *Standard Oil Company of Louisiana, Baton Rouge, Louisiana*

IN DETERMINING the limit of identification for microscopical reagents relatively easily manipulated capillary pipets are indispensable. Such pipets, for measurements of volumes of the order of 0.1 to 10 cubic millimeters, are ordinarily made[1] from drawn capillaries having uniform bores between 0.1 and 0.7 mm. in diameter. The actual bore is generally measured on short segments, vertically mounted on a microscope slide, by means of calibrated ocular micrometers. The length of capillary corresponding to a desired volume (usually 1 or 10 mm.^{3}) is then calculated and volumes of liquid measured by placing the capillary over a centimeter rule. Because of their fragility, the life of these capillaries is quite short unless extreme care is used.

Figure 1 illustrates a form of protected calibrated pipet that the authors have used for about three years. When adopted for use in a student laboratory (course in chemical microscopy at The Louisiana State University) appreciable saving of time resulted since each student merely needed to prepare a single pipet for each desired range. These were generally long-lived enough for the duration of the course and it was not necessary for students to repeat the capillary drawing and measuring frequently.

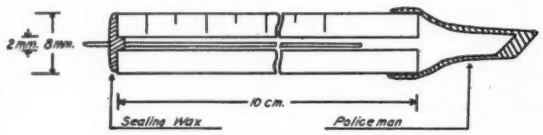


FIGURE 1

The following directions were followed in preparing a pipet for delivering 0.1 mm.^{3} volumes (total capacity 5 mm.^{3}). Pipets in other desired ranges were prepared in similar fashion by merely choosing the correct capillary bore. The ruggedness of the pipets made it profitable to exercise greater than usual care in the choice of the capillary from the point of view of uniformity and convenience of bore diameter.

A series of capillaries about 25 cm. in length were carefully drawn. One was chosen having a bore of approximately 0.35 mm., and the inside diameter accurately measured on three segments (one cut off each end and one from the middle). A 10-cm. length of heavy-wall 2-mm. stock capillary tubing (approximately 8 mm. o.d.) was then taken and the ends fire-polished or ground. In one specific instance the pipet capillary proved to have an actual average diameter of 0.37 mm. The length of this capillary corresponding to a volume of one mm.^{3} was then calculated as being 9.5 mm. Lines were then etched (one-fourth around) every 9.5 mm. on the heavy-walled tube, starting from one end. A second set of divisions was then etched (one-half around) halfway between the initial marks. A 9-cm. length of the pipet capillary was then taken and one end (delivery tip) drawn down sharply. This capillary was then inserted into the tubing and sealed in place with a minimum of black sealing cement so that exactly 5 mm. of the drawn end protruded. An ordinary rubber policeman was slipped over the opposite end of the tube. This pipet could be read directly to 0.5 mm.^{3} and closely estimated to 0.1 mm.^{3}

The pipets are best used by holding so that the policeman is grasped between the thumb and forefinger with the tube lying across the palm of the hand. By resting the edge of the hand on the desk top, touching the protruding tip of the pipet to a drop of the solution to be measured, and gently manipulating the policeman in the manner of a dropper bulb it is possible to take in (for dilution purposes) and deliver desired volumes accurately and carefully. It is not necessary either to adjust the tilt of the capillary to assure taking in sufficient liquid by capillarity, or to blow on the end for delivery. With little practice accurate dilutions may be made, and by careful control of the pressure on the rubber bulb complete control of the liquid in the pipet is assured. The meniscus is readily visible through the larger tubing. Reasonable care, of course, must be taken to prevent drawing in so large an excess of solution as to permit it to flow into the annular space between the capillary and the inner wall of the tubing. Regulating the compressible air space in the policeman by forcing it further onto the tubing facilitates matters greatly. By choosing a small-bore policeman it is usually possible to adjust conditions so that an ordinary squeeze on the bulb will permit only the drawing in of sufficient solution to fill the capillary to within a centimeter or so of the end.

A rubber stopper or cork fitted just below the policeman permits sealed storage of the pipet in an appropriate test tube. In lieu of etched markings on the tube, file scratches may be used. The resulting pipet will be serviceable, though not as attractive in appearance. If desired, a narrow strip of millimeter-ruled graph paper may be cemented or glued, with the rulings adjacent to the glass, to the under side of the tube and the divisions used as calibration marks. The unused pieces of drawn capillary may be formed into duplicate pipets or stored in the same test tube and used in the originally calibrated tubing when, or if, the original capillary is broken. With only a short length of the

[1] BENEDETTI-PICHLER AND SPIKES, "Microtechnique of inorganic qualitative analysis," Microchemical Service, Douglaston, N. Y., 1935, pp. 36, 60.

fragile capillary protruding the pipet will weather rather rough treatment. Usually, in case of accidents, the tip only is broken and the pipet may easily be made serviceable again by removing the policeman, warming the sealing cement, and pushing out the capillary until the desired length of tip again protrudes.

MIXED INDICATORS IN THE ELEMENTARY QUANTITATIVE ANALYSIS COURSE

W. S. McGUIRE

Northeastern University, Boston, Massachusetts

EVER since Lunge[1] suggested the use of methyl orange as an indicator to replace the previously used natural dyestuffs, students as well as mature chemists have had difficulty in deciding upon the exact shade to take as the endpoint of the titration. While some chemists have recommended as a means of comparison the use of a buffer solution of the correct pH containing the same volume of liquid and of indicator, the additional labor is often unwarranted, particularly if the operator is even slightly color blind.

The idea of increasing the sharpness of this and other difficult endpoints by the addition of either a second indicator of similar range and contrasting color, or of inert dye which retained its own color throughout the interval, apparently originated with Scholtz.[2] He prepared a large number of such mixtures, including one in which the desired effect was produced by the addition of indigo-carmine to the methyl orange. This mixture, the use of which was revived by Moerk,[3] has never been entirely satisfactory. In 1922, Hickman and Linstead[4] suggested the addition of an inert blue dye, xylene cyanol FF, to the methyl orange, thus giving a color change from green to magenta through a gray at pH 4. This modified or "masked" indicator has been used for a number of years at Northeastern University with marked success. However, it has been found that students titrating with fairly strong solutions failed to obtain a gray color, but instead a mixed one showing marked dichromatism. This effect seems partly due to the variation in strength of the dye used, which was found to vary not only with samples from different sources but also with those from the same source. Others both in this country and in England[5] have apparently had similar experiences.

Accordingly, a search was made for a more satisfactory mixture in this pH range, and several, including the methyl orange-indigo-carmine mixture of Scholtz, were investigated. It was found that a mixture of bromcresol green with methyl orange gave a sharp color change from blue in alkaline solution to yellow in acid, going through green at pH 4.3. Several concentrations of this mixture were tried, the best results being obtained with the preparation recommended by Hull.[6] In this case one gram of bromcresol green and 0.2 gram of methyl orange were ground up with 50 ml. of $N/10$ sodium hydroxide and the resulting solution diluted to a liter. Using four or five drops of this indicator to a volume of 150 ml., over fifty students have made several hundred acid-base titrations with very little trouble and few failures. While this is a much more expensive indicator than the simple methyl orange, the net cost per student is still very small.

Mixed indicators covering other ranges have been tried. The "Universal" indicator of Smith[7] was found to be a very satisfactory substitute for the usual phenolphthalein, giving a change from green to red through a practically colorless solution at pH 8.5. However, since students have very little difficulty with the regular colorless to red change, there is not such a demand for a mixed indicator in this interval. As an example of a mixed indicator in the neutral range, that composed of neutral red and methylene blue, with a change from blue-violet to green, through a colorless gray at pH 7, was found to be suitable for the titration of ammonia with acetic acid, something usually not considered feasible. A mixture of equal parts of each, as suggested by Vogel,[8] was not found satisfactory, probably due to the variation of dye content in the indicators used. Best results were obtained with a 2:3 ratio of neutral red to methylene blue. This is an excellent example of the decreased interval necessary for a sharp color change when mixed indicators are used. A similar mixture[9] prepared by adding methylene blue to methyl red gives a color change from red-purple to green in the usual ammonia titration, even when the semimicro Kjeldahl method is used.

While there are a number of other excellent mixed indicators available, these mentioned are of sufficient value to be included in the usual elementary course as examples of the ease and improved precision made possible by their use.

[1] LUNGE, *Ber.*, **11**, 1944 (1878).
[2] SCHOLTZ, *Z. Elektrochem.*, **10**, 549 (1904).
[3] MOERK, *Am. J. Pharm.*, **93**, 675 (1921).
[4] HICKMAN AND LINSTEAD, *J. Chem. Soc.*, **121**, 2502 (1922).
[5] INNES, *Analyst*, **64**, 19 (1939).
[6] HULL, *Public Works*, **10**, No. 4, 34 (1939).
[7] SMITH, *Pharm. J.*, **71**, (4), 101 (1930).
[8] VOGEL, "Textbook of quantitative inorganic analysis," Longmans, Green and Co., London, 1939, p. 68.
[9] JOHNSON AND GREEN, *Ind. Eng. Chem., Anal. Ed.*, **2**, 2 (1930).

Effect of Concentration on Reaction Rate and Equilibrium

ARTHUR A. FROST *Northwestern University, Evanston, Illinois*

TEXTBOOK CONFUSION

IT WOULD be very confusing to a student to compare discussions of the Law of Mass Action in different texts of general or physical chemistry. There is no general agreement as to what the Law of Mass Action really is. In a survey of fifteen textbooks it was found that, according to seven, the Law of Mass Action is a relation between velocity of reaction and concentration, whereas in five the law s considered to be the equilibrium constant expression for a reaction. One author resolves the difficulty in terminology by stating a Mass Action Law of Reaction Rate and also a Mass Action Law of Chemical Equilibrium. Other authors present the usual discussion of rate and equilibrium without using the term "mass action" or the expression "Law of Mass Action."

A decision as to the validity of a particular statement of the law could be obtained by referring back to Guldberg and Waage,[1] who first stated the law. In a series of papers appearing from 1864 to 1879 they reported measurements of reaction rate and equilibrium and interpreted the effect of change in concentration in terms of their theoretical ideas. After generalizing from experimental facts and theory that the rate of a reaction was proportional to the concentrations of the reactants, each concentration raised to a power equal to the coefficient of the corresponding substance in the chemical equation, they derived equilibrium expressions by equating the rates of forward and reverse reactions. In their 1879 article[2] they apply the expression "Law of Mass Action" to the statement of the effect of concentration on rate of reaction and use the term "Condition of Equilibrium" for the relation between concentrations at equilibrium. On this basis we could decide which texts are correct. However, there appears to be a more fundamental difficulty than just one of terminology.

IS THE LAW OF MASS ACTION VALID?

In experimental studies of the rate of a reaction the rate may be determined as a function of concentration, other conditions assumed constant. Usually the function, or rate expression, will take the simple form of a product of powers of concentrations

$$\text{rate} = k[A]^p[B]^q[C]^r \ldots$$

where k is the rate constant, $[A]$, $[B]$, etc., are concentrations of substances A, B, etc., which may be reactants, products, catalysts, etc., and p, q, r, etc., take on values such as 1, 2, or 3 but may sometimes be fractional or negative. Now according to the usual statement of the Law of Mass Action the rate expression is of this simple form but restricted so that A, B, C, etc., are reactants only and p, q, r, etc., are the stoichiometric coefficients of the reactants in the chemical equation. The Law of Mass Action, if expressed in this form, is certainly not valid, since very few reactions have rate expressions corresponding to their stoichiometric equations. Of course, the reason for this is that most reactions are complex, *i. e.*, proceed in steps, the rate being determined by the slowest step (or combination of steps if there are steps competing with each other). By restricting the law to simple reactions, the law would hold. It is correct to say that for simple homogeneous reactions, or for a single step in a complex reaction, the rate is proportional to the concentration of each reactant raised to a power equal to the number of molecules of that reactant taking part in the process.

Although when restricted as above the Law of Mass Action is correct, it can hardly be called a law of nature. A law of nature is supposed to be a generalization from experiment. The above statement of the law is certainly not a generalization from experiment, since to verify the law one must know whether or not a given reaction is simple or complex, and the only general experimental method for determining this is to work the "law" backwards after testing the dependence of rate on concentration. Nevertheless, the statement is important since it is a result of the application of kinetic theory or of statistical mechanics. Also it is the basis for the derivation of complicated rate expressions when the mechanism of a complex reaction is known. It would be more appropriate to speak of the Theorem, or Principle, of Mass Action rather than the Law. Actual mechanisms are "discovered" by assuming that the "theorem" of mass action applies to the steps of a reaction. Hypothetical steps are then set up in such fashion that they agree with experimental data.

Those authors who apply the term "Law of Mass Action" to the equilibrium relationship between concentrations are justified to the extent that the general equilibrium relationship is at least a law of nature and holds for both simple and complex reactions. Furthermore, Guldberg and Waage carried out more experiments relating to equilibrium than to rate. They used the theoretical rate expressions primarily to derive the condition of equilibrium.

The conclusion from the argument of this section

[1] GULDBERG AND WAAGE. Collected papers may be found in OSTWALD'S "Klassiker der Exakten Wissenschaften," Wilhelm Engelmann, Leipzig, 1899, No. 104, 182 pp.

[2] GULDBERG AND WAAGE, *J. prakt. Chem.*, 19, 71 (1879).

is that the expression "Law of Mass Action" is both false and misleading and should be deleted from the literature.

KINETIC DERIVATION OF THE CONDITION OF EQUILIBRIUM

The only completely satisfactory derivation of the general equilibrium relationship is that given by thermodynamics or statistical mechanics. However, the kinetic picture of equilibrium has such great pedagogic value that it should certainly be presented to students if it can be done without being misleading.

Most texts follow the lead of Guldberg and Waage in giving a simple kinetic derivation of the condition of equilibrium. As ordinarily presented, the derivation is limited to simple reactions although this limitation is hardly ever mentioned. There is great need for making a clearer distinction between simple and complex reactions so that the student will not be misled to believe that rate expressions for all reactions can be predicted from their stoichiometric equations.

The author has not been able to find in the literature a general kinetic derivation of the equilibrium condition which holds for complex reactions. The following are derivations which apply, first, to a particular example of a complex reaction,[3] then, to any complex homogeneous reaction of perfect gases or of solutes in liquid solution at low concentration.

AN EXAMPLE OF A COMPLEX REACTION

Consider the reaction

$$AB = A + B$$

which takes place by the mechanism

$$AB + X \longrightarrow AX + B$$
$$AX \longrightarrow A + X$$

According to the principle of microscopic reversibility, or detailed balancing, at equilibrium each step will be in equilibrium and the rate of the forward reaction will be equal to the rate of the reverse reaction. For the first step, according to kinetic theory or the "theorem" of mass action

$$\text{forward rate} = k_1[AB][X]$$
$$\text{reverse rate} = k_1'[AX][B]$$

and

$$k_1[AB][X] = k_1'[AX][B]$$

or

$$\frac{k_1}{k_1'} = K_1 = \frac{[AX][B]}{[AB][X]}$$

which is the equilibrium constant expression for the first step. For the second step, similarly

$$\frac{k_2}{k_2'} = K_2 = \frac{[A][X]}{[AX]}$$

Now turning back to the chemical equations for the reaction steps, it is clear that the sum of the reaction equations gives the overall or stoichiometric equation, X and AX canceling out. In like manner, if the two equilibrium expressions are multiplied together the concentrations of X and AX cancel out and the result is

$$K_1K_2 = K = \frac{[A][B]}{[AB]}$$

which is the equilibrium expression for the overall reaction.

A GENERAL DERIVATION OF THE CONDITION FOR EQUILIBRIUM

The derivation for the general case of any complex homogeneous reaction of perfect gases or ideal solutions is similar to the above, the idea being that when reaction steps are added the corresponding equilibrium expressions are multiplied together. This procedure insures that concentrations of catalysts and intermediates cancel out from the final equilibrium expression for the reaction as a whole.

To simplify the algebra a different notation will be used. A reaction step will be expressed by placing all molecules on the right side of the equation, reacting molecules being then given a negative coefficient. For example, the first step in the reaction discussed above would be written

$$\longrightarrow AX + B - AB - X$$

meaning that AX and B are formed from AB and X.

Let the steps in the general reaction be

$$\longrightarrow p_aA + p_bB + p_cC + \ldots$$
$$\longrightarrow q_aA + q_bB + q_cC + \ldots$$
$$\longrightarrow r_aA + r_bB + r_cC + \ldots$$

where A, B, C, etc., are molecular species involved in the reaction and the p's, q's, r's, etc., represent numerical coefficients showing the number of molecules of each kind which are involved in a particular step, a negative value of the coefficient indicating that the corresponding molecular species is a reactant in that step. All molecular species are indicated in each expression for a reaction step. A zero coefficient would mean that the particular species either does not take part in that reaction step or else that if it does take part it remains unchanged. (The latter provides for the case of a third body in a collision for the removal of energy or for the reverse process.)

At equilibrium each step is in equilibrium and the forward rate equals the reverse rate. If k_1 and k_1' are rate constants for the forward and reverse of the first step,

$$k_1[A]^{-p_a}[B]^{-p_b} \ldots = k_1'[C]^{p_c}[D]^{p_d} \ldots$$

where the molecular species are placed on one side or the other depending upon the signs of the coefficients, *i. e.*, whether they are reactants in the forward step or reverse step. In the above, p_a and p_b were supposed to be negative, meaning that A and B were reactants in the forward step. Upon rearranging the equation so that all concentrations are on the right and the constants on the left, we have

[3] Such an example is given in HILDEBRAND, "Principles of chemistry," 4th ed., The Macmillan Co., New York City, 1940, p. 159.

$$\frac{k_1}{k_1'} = K_p = [A]^{p_a}[B]^{p_b}[C]^{p_c}[D]^{p_d}\ldots$$

which is the equilibrium expression for the first reaction step. It should be noticed that this expression has the same albebraic form regardless of which substances are reactants or products. Similarly for the other steps

$$K_q = [A]^{q_a}[B]^{q_b}[C]^{q_c}[D]^{q_d}\ \ldots, \text{ etc.}$$

These expressions all hold simultaneously so they may be combined algebraically. Suppose that the chemical equations for the reaction steps are added together in such a way that the stoichiometric equation is obtained. This may require multiplying some of the steps by a simple number. Let the stoichiometric equation be

$$\longrightarrow x_aA + x_bB + x_cC \ldots$$

where

$$x_a = n_pp_a + n_qq_a + n_rr_a + \ldots$$
$$x_b = n_pp_b + n_qq_b + n_rr_b + \ldots$$

the coefficients n_p, n_q, n_r, ... being small whole numbers, chosen in such a way that the x's for the catalysts and intermediates are zero. (If these were not zero, it would mean the catalyst or intermediate molecules would appear in the stoichiometric equation.) Now combine the equilibrium expressions for each step by multiplying together after raising each to the corresponding power

$$n_p, n_q, \ldots$$
$$K_p^{n_p}K_q^{n_q}\ \ldots = [A]^{n_pp_a+n_qq_a+}\cdot[B]^{n_pp_a+n_qq_a+}\ \ldots$$

but

$$n_pp_a + n_qq_a + \ldots = X_a, \text{ etc.}$$

Let K replace the product $K_p^{n_p}K_q^{n_q}\ldots$

then

$$K = [A]^{x_a}[B]^{x_b}[C]^{x_c}\ \ldots$$

which is the desired equilibrium expression for the stoichiometric equation of the complex reaction as a whole.

A derivation such as this would be out of place in elementary texts but it would be very desirable that when the ordinary derivation is given it be explicitly stated that it applies only to simple reactions.

Recent Advances in the Chemistry of the Proteins[1]

DWIGHT C. CARPENTER

Physico-Chemical Laboratory, New York State Experiment Station, Geneva, New York

DESPITE the fact that protein chemistry dates back some two hundred years to the separation of gluten from flour in 1747 by Beccari, there is no protein to which we may point and say that its chemical structure is known. Of course the amounts of the various amino acids comprising the various proteins have been approximately known, as well as could be determined with the comparatively crude analytical methods used and the protein samples employed, which often consisted of a mixture of several chemical entities.

It has been only since the development of the ultracentrifuge by Svedberg (*1*) in 1924 that it has been possible to determine with any certainty even so fundamental a thing as the molecular weight of a protein. The centrifuge also enables us to tell whether a given protein sample is contaminated with other proteins of greater or smaller molecular weight. The molecular weight of the simplest protein yet found is 17,600, and that of the most complex around 20 million. It is evident that a huge number of the various amino acids is contained in even the smallest of such molecules.

In 1883 Curtius obtained glycine anhydride by heating the ethyl ester of glycine. In 1901 it occurred to Emil Fischer (*2*) that if this anhydride ring could be broken he would have glycylglycine, a dipeptide. This was the beginning of a series of organic syntheses that claimed Fischer's attention for many years. Although Fischer made a great many peptides, some of which had a dozen or more amino acids, by uniting these acids together, he knew that his synthetic products were a long way short of being any protein and was content to say that as the number of amino-acid linkages was progressively increased, the more the resultant product "resembled" a protein in its properties. Many supposed from Fischer's work that proteins were long thread-like molecules consisting of a long chain of amino acids. However it remained for the ultracentrifuge to show that many protein molecules are nearly spherical in shape. For instance, the egg-albumin molecule could be either a sphere or a cube with a diameter or side of about 40 A. As far as we can judge, few protein molecules seem to have a length of more than four or five times their other dimensions[2] and so we are forced to conclude that the thread-like amino-acid chains must be of lengths of about 40 A.

[1] Approved by the Director of the New York State Experiment Station for publication as Journal Paper No. 420.

Synopsis of an address given before the Rochester Dietetic Association, Rochester, New York, December 16, 1940.

[2] With the electron microscope Stanley has found that the tobacco mosaic virus has dimensions 180 by 2800 A. [*Science*, **93**, 145 (1941)].

and laid parallel to one another—or if they form a long chain, this chain must be looped back upon itself every 40 A. or so.

Astbury (*3*) examined several powdered proteins and silk with X-rays and found that the concentric ring patterns he obtained yielded certain interatomic distances that were fairly constant for all proteins; for instance, the distances 3.5, 4.5, and 10 A. were encountered regularly. In framing a general picture of how these molecules were put together, Astbury concluded that amino acids formed chains in which the distance from the nitrogen atom of one amino acid to the nitrogen of the next amino acid was 3.5 A. He thought several of these chains of amino acids lay parallel to each other and 4.5 A. apart in a sort of flat two-dimensional layer. These flat layers were then piled one on another, 10 A. apart, to give the three-dimensional figure of the molecule.

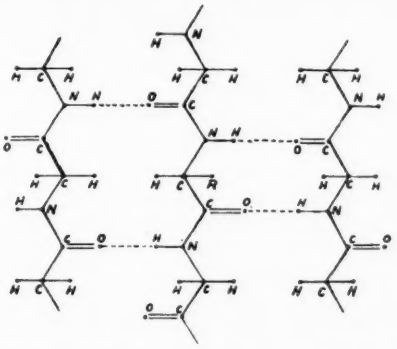


FIGURE 1.—PEPTIDE CHAINS HELD BY H-BOND LINKAGE

How the parallel amino-acid chains were held to one another, 4.5 A. apart, in the flat layer-level, and how the layer-levels were held together 10 A. apart has been a matter of conjecture. Mirsky and Pauling (*4*) have advanced the idea that the parallel chains are held together by hydrogen-bond linkages between a C=O group of one amino-acid chain and an H—N group of an adjacent chain, yielding a COHN linkage between chains. This sort of bonding would lead to a calculated distance of 4.65 A. between chains and is shown in Figure 1. We have also calculated the distance between chains if they were held together by the side-chain —S—S— linkage of cystine, assuming one cystein residue in each adjacent chain. The distance works out to be 4.65 A. Either of these types of linkage could occur in proteins and hold parallel chains together, and both distances are compatible in magnitude with the 4.5 A. distance found by Astbury.

The layer-layer levels may be held together only by linkages between glutamic acid and arginine or lysine, as these are the only amino acids with side-chain groups of sufficient length even to approximate the required 10 A. If this linkage be a hydrogen-bond union, the calculated layer-layer distance turns out to be 9.94 A. If the linkage is that of compound formation between the terminal NH_2 and COOH groups of the two side-chains of the respective acids, then the calculated layer-layer distance is 10.42 A. Either of these calculated values is within the errors of the X-ray method establishing the layer-layer distance at 10 A.

We do not know the heat of dissociation of any protein, but it is evident that they dissociate easily and hence the number of layer to layer bonds which are broken is either small in number or the bond energy of each layer-layer union is small. Perhaps both of the linkages mentioned above are equally probable as an explanation of how the layer-layer levels of the molecule are tied together.

Bergmann and Niemann (*5*) have noted in several proteins that the number of times a given amino acid appears in the protein molecule is given by the expression

$$N = 2^n \times 3^m$$

where n and m are whole positive numbers ranging from zero to perhaps five. This may mean that a given amino acid repeats in the molecular structure at regular intervals. For silk fibroin they suggest that the order is

–T–G–A–G–X–G–A–G–X–G–A–G–X–G–A–G–T

where T represents tyrosine, G glycine, A alanine, and X some other amino acid. Interesting as this observation may be, it appears doubtful that the present analytical methods for determining amino acids in protein digests are sufficiently reliable to establish any such exact relationship as that given. Only a few workers seem to realize that a quantitative recovery of the various amino acids contained in a protein is possible in only a few cases and under closely controlled conditions.

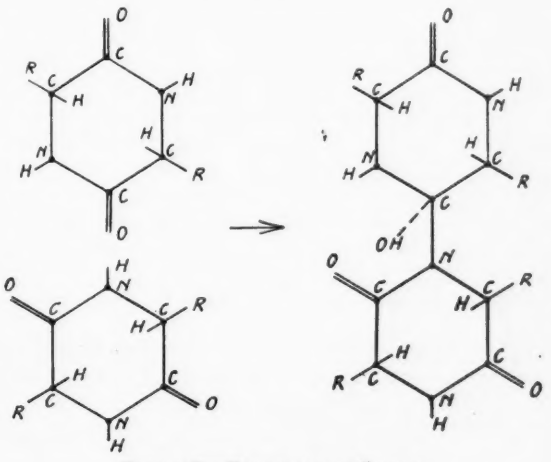


FIGURE 2.—FORMATION OF CYCLOL

Wrinch (*6*) has proposed that instead of a protein being built of long parallel chains of amino acids, the

amino acids are present as ketopiperazine rings (cyclol hypothesis) united together between the carbon atom of a CO group and the nitrogen atom of an NH group of a second ketopiperazine molecule, the amino hydrogen moving onto the oxygen of the first ketone group to give an OH group which is above or below the general plane of the rings. This sort of linkage is shown in Figure 2. Wrinch has been fairly successful in developing an octahedral structure for the insulin molecule based on this type of union.

Another type of ketopiperazine structure is suggested by Figure 3, in which the ketopiperazine rings are bound to each other by four hydrogen-bond linkages (COHN). On account of the low bond energy of the hydrogen bond, a protein built in this fashion should be easily disintegrated.

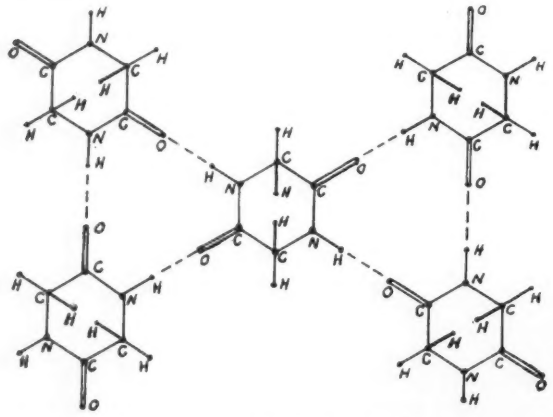
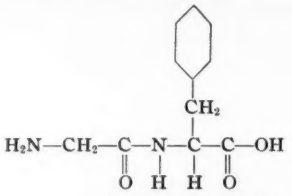


FIGURE 3.—KETOPIPERAZINE RINGS HELD BY H-BOND LINKAGE

During the past year (*7*) work has been in progress on the splitting of proteins and allied substances by means of ultra-violet light, which leads us to believe that we may crack open a protein at certain restricted points without breaking the molecule all to pieces. This method of attack should enable us to decide whether the amino acids existed as chains or ketopiperazine rings, and, furthermore, how far from the end of a protein molecule a specific light-absorbing group (phenyl, phenolic, indol, etc.) was situated, and whether or not the amino acid in question occurred at definite intervals. The fundamental part of the work referred to has not been done on proteins at all but on comparatively simple organic compounds of known structure, having linkages like those that occur in proteins.

. Rideal and Mitchell (*8*) recently noted that when stearic anilide, $C_{17}H_{35}CONHC_6H_5$, was exposed as a monolayer to ultra-violet light of wave length 2537 A., splitting of the CONH linkage occurred and stearic acid and aniline were produced. A substance must absorb light energy in order to use it; consequently only under conditions where light is absorbed can a reaction take place. In the stearic anilide experiment the aniline (benzene ring) part of the molecule absorbs light energy, activating the molecule so that it reacts chemically. In aniline it would be expected that most of the energy absorbed by the benzene ring would pass to the adjacent nitrogen atom, and this would be the site of chemical activity. If we try to apply the idea of splitting by light energy to simple amino-acid compounds such as glycyl-phenyl alanine, we find that the light energy absorbed by the ring is a long way from the CONH linkage, where splitting is most liable to occur.



glycyl-phenyl alanine

In order to be applicable to protein substances, it must be shown that absorbed light energy can travel through several atoms of a molecule until it reaches the spot where the bond energy is weakest and a splitting can occur. In developing the experimental work along this line, first one CH_2 group was interposed between the ring and the CONH linkage (benzyl stearyl amine, $C_{17}H_{35}CONHCH_2C_6H_5$), and next two CH_2 groups were interposed (β-phenyl-ethyl stearyl amine, $C_{17}H_{35}CONH(CH_2)_2C_6H_5$). When any of these substances are exposed to ultra-violet light, of wave length 2537 A., they break at the CONH linkage, thereby showing that absorbed light energy may travel in a molecule. We may safely expect, therefore, that a peptide chain will be broken adjacent to any amino acid carrying a light-absorbing side-chain. Consequently, by varying the incident light we can break a peptide chain at whatever point we please. Protein molecules have already been broken at the point where tyrosine occurs.

It is expected that breaking protein molecules by means of ultra-violet light will enable us to decide between the chain and cyclol hypotheses of structure, and throw more light upon the order in which the amino acids are arranged in proteins. Last, and by no means least, it will give us information about the physiologically active part of specialized protein molecules, such as insulin, so that their synthesis may be possible.

LITERATURE CITED

(1) SVEDBERG AND RINDE, *J. Am. Chem. Soc.*, **46**, 2677 (1924).
(2) FISCHER, *Ber.*, **38**, 607 (1905).
(3) ASTBURY, *Nature*, **132**, 593 (1933).
(4) MIRSKY AND PAULING, *Proc. Nat. Acad. Sci.*, **22**, 439 (1936).
(5) BERGMANN AND NIEMANN, *Science*, **86**, 187 (1937).
(6) WRINCH, *Nature*, **137**, 411 (1936).
(7) CARPENTER, *Science*, **89**, 251 (1939); *J. Am. Chem. Soc.*, **62**, 289 (1940).
(8) RIDEAL AND MITCHELL, *Proc. Roy. Soc.* (London), **159A**, 206 (1937).

A History of the Match Industry[1]

M. F. CRASS, JR. *Washington, D. C.*

PART III—PHOSPHORUS MATCHES

CREDIT for the first phosphorus match is given to a Frenchman, Dr. Charles Sauria of St. Lothair (*1*). Dr. Sauria made his phosphorus-tipped splints late in 1830, with a formula essentially the same as that used for lucifers except that phosphorus was substituted for antimony sulfide. There were undoubtedly earlier attempts that were either unpublicized or unsuccessful.

The first American match patent, Number 68, was granted to Alonzo Dwight Phillips, a powder maker of Springfield, Massachusetts, on October 24, 1836, the patent describing "new and useful improvements in modes of manufacturing friction-matches for the instantaneous production of light." The patent specification reads in part as follows:

"The composition used in preparing the matches usually called LocoFoco and which light by slight friction, is a compound of phosphorus, chlorate of potash, sulphuret of antimony, and gum arabic or glue. That which I use consists simply of phosphorus, chalk, and glue, and in preparing it I use the ingredients in the following manner and proportions: I take 1 oz. of glue and dissolve it by the aid of water and heat in the usual manner; to this glue I add 4 oz. of finely pulverized chalk or Spanish White, stirring it in so as to form a thick paste. I then put in one ounce of phosphorus, keeping the materials at such degree of heat as will suffice to melt the phosphorus and incorporate the whole together. Into this composition the matches are dipped after previously being dipped in sulfur in the usual manner."

Although Phillips' patent was the first patent relating to matches to be granted in the United States, it is apparent from the above that phosphorus matches, similar in formula to those of Dr. Sauria, had been previously used. John Hatfield is given credit for the production of this type of match in 1835. It is interesting to note, also, that sulfur dipping was apparently common practice, even at this early date. Phillips' patent also included directions for cutting, preparing, and safely packaging the dipped splints.

Although it is probable that Phillips' formula was used to some extent because of its purchase a short time after its date of issuance by Ezekial Byam, the first important American match manufacturer, most of the phosphorus matches contained potassium chlorate or some other oxidizing agent to facilitate ready ignition, since the demand for a match with easy striking qualities was paramount after widespread use of the hard-striking lucifer.

In 1839 John H. Stevens was granted a patent (*2*) covering the use of oxides of lead and manganese in match compositions, it being claimed that the presence of these ingredients quickened the drying operation and made the heads harder and more durable, "causing the heads to retain their specific character longer than other matches previously compounded and to produce a more brilliant and beautiful light than any composition heretofore known."

In England, phosphorus matches were called "Congreves," which suggests that the new product was not in all cases a mild one inasmuch as the term was used in special honor of Sir William Congreve, the inventor of the war rocket. In America, the term "loco foco" continued to be applied to phosphorus matches for many years. Although most of the phosphorus matches were sulfur-dipped, ignition tips were smaller than those of the earlier lucifer matches for the reason that much less frictional force was required for their ignition. Acceptance of the phosphorus friction match by both Americans and Europeans was widespread and by 1835 most of the earlier methods of firemaking had been abandoned except in the outlying districts or territories, where the tinder box continued to be used.

The chemical nature of the phosphorus friction match did not change appreciably between the years 1830 and 1890. Many improvements in composition were made in order to control sensitivity, rate of burning, resistance to moisture, etc., but the fundamental principle upon which the match was based, *i. e.*, sensitivity of phosphorus to friction, was not altered. Improvements made in the period noted above included the following:

1. Chemical changes in composition
2. Substitution of paraffin for sulfur as a flame transmission agent
3. Moisture proofing the match head
4. Splint impregnation for the prevention of afterglow

Chemical Changes in Composition

As time went on, the phosphorus content of the sensitive ignition tip was gradually reduced, especially in Europe, where the effects of phosphorus poisoning upon match factory employees appeared to cause greater concern than in this country. The following formulas tend to emphasize this fact:

CONGREVE COMPOSITIONS

Material	*German 1835*	*German 1838–40*	*German 1840*	*German 1840–50*	*Austrian 1840–50*	*Austrian 1860*
Phosphorus	20.5	10.5	13.0	6.9	17.8	5.5
Sulfur	14.3	12.7	9.0	20.4	11.5	3.2
Chlorate	32.1	43.3	60.7	39.0	37.4	54.8
Chalk	8.0	12.5	..	..	..	..
Gum	..	21.0	..	..	33.0	36.5
Dextrin	25.1	..	17.3	..	..	..
Glue	..	..	..	33.7	..	..

In 1844 Elisha Smith introduced the use of pulverized tannin-containing vegetable materials such as finely ground hemlock or oak bark, sumac or nutgalls, as substitutes for inert filling ingredients in match composi-

[1] Continued from the March, 1941, issue.

tions, claiming that they protected the phosphorus from oxidation and moisture absorption (*3*). Smith gave an interesting description of the matches then in use, stating that the general use of earthy materials as phosphorus protectors "resulted in explosions and the blowing out of the flame when the matches are ignited. Small globules of inflamed composition are often ejected from the burning match, which are liable to produce serious results such as the burning of the eyes or other exposed parts of the user."

There can be no doubt regarding the hazards connected with the use of these early products. A later account (1865) states (*1*): "The too-great sensibility of (phosphorus) matches is the principal cause of these terrible explosions and accidents, the same that their too great explosibility is the ordinary cause of the burns in the face and eyes. The sensibility is such that we have seen packages of matches take fire in the hands without knowing how it happens."

The use of sulfur as a compounding ingredient in match composition was patented (*4*) by Blaisdell in 1842, while Carleton took out a patent in the same year, claiming that a reduction in the phosphorus content of match composition could be made by substituting combustible materials for inert ingredients. Carleton used potassium carbonate and potassium nitrate, together with phosphorus and gum arabic, in his ignition mixture.

In 1867 E. I. Smith patented (*5*) the use of nitric acid in combination with red lead, claiming that the resulting composition "was not fulminating in character, ignited particles are not apt to be discharged from the match when the latter is struck, and the danger of setting fire to adjacent objects is avoided." The nitric acid and lead oxide were first mixed together and then added to the phosphorus-glue solution. No mention was made in the patent of the type of mixing vessel employed.

A parlor match introduced in 1880 made use of turpentine in the phosphorus composition, which, it was claimed, reduced the working temperature of the batch to 90°F. in place of the 140° temperature previously required for keeping the phosphorus in a molten condition (*6*). According to the inventor, "less poisonous fumes are given off to injure workmen because of the lower temperature used. The match head, consisting of pulverized flint, saltpeter, glue, phosphorus, crocus metallorum, and turpentine burns without explosions, will endure any climate, will not ignite by being stepped upon, but is sure to fire when subjected to the proper friction."

That certain improvements were made in phosphorus friction matches during this period is shown by the following account, published in 1874 (*7*):

> "It was found that the simple splint of soft wood, first dipped in melted sulphur and then in paste made of phosphorus and glue, with a little fine sand and red ochre, supplied the most convenient, cheap, and safe match that could possibly be devised. This is the match which has held its place up to the present time and is in common use domestically in all parts of the civilized world."

Regarding phosphorus, the article continues:

> "Friction match manufacturers first paid as high as $250 per pound for phosphorus. When preparation began from bones, however, the price dropped. The production from bones requires a large consumption of fuel, 100 pounds of coal being required to secure one pound of the element, and the intensity of the heat is such as to rapidly destroy apparatus. The labour, also, is not only disagreeable but dangerous, as through inattention fearful explosions of the retort may occur. It was for a time feared that the demand for bones for agricultural purposes would so enhance the cost and diminish the supply as to raise the price of phosphorus to a high point. Discovery of phosphatic rocks in this country has been recently made, however, and no one need be anxious concerning a full supply at cheap rates of the indispensable friction matches, during his lifetime, at least."

Another author, in 1877, wrote as follows (*8*):

> "The sulphur match now in use is not as old as the railroads and but a few years ago there occurred frequent examples of burns caused by the explosion of the match and the projection of its burning particles."

To avoid fire risk, or rather to keep such risk down to a minimum, phosphorus matches were often packed in bran, and kept in special non-flammable boxes made of metal, so as to prevent the spread of fire in case the matches became ignited.

Parlor Matches

The first recorded use of a material other than sulfur for dipping match splints, prior to tipping with ignitable composition, came in 1843, when William Ashard was granted a patent for the use of molten beeswax or other similar material in place of sulfur (*9*). The patent specification stated that "sulphur is well known to be disagreeable and deleterious, and particularly injurious to persons with weak lungs and delicate constitutions." Not content with eradicating the odor of burning sulfur, Ashard also perfumed his splints "so that an agreeable fragrance is exhaled." The prohibitive cost of beeswax prevented wide application of this material as a substitute for sulfur, however. Likewise, the use of stearic acid as a flame transmission agent, while practiced to a limited extent, was restricted because of its high cost. The use of sulfur as a flame transmission agent was not only undesirable from the standpoint of the fumes produced, but also because it was necessary for the user to wait until the sulfur had all been consumed before the wood splint took fire.

Rosin and naphthalene were suggested for use at different times, but objections were many and there is nothing to indicate even limited application of these materials as flame transmission agents. To impart added fragrance to the odor of burning matches, some manufacturers added camphor, frankincense, or gum benzoin to the compositions of some of the more expensive "luxury" matches. These aromatic materials, on red cedar splints, overcame most of the other match odors and "gave out such a delicate fragrance that it was a pleasure merely to light them."

That oleic acid was used to a certain extent in order to convey the flame from the match head to the splint

is shown by a patent (*10*) taken out in 1883 which proposed the use of litharge and zinc oxide as composition ingredients, in order to make the heads adhere tightly to cardboard splints which were impregnated with oleic acid.

In 1862, the use of paraffin wax for splint treatment was patented (*11*) by Charles W. Smith, and the resulting "parlor matches," so called because of their universal adoption by polite society in order to avoid the obnoxious fumes so prevalent with the sulfured match, marks one of the important milestones in the history of the industry. That paraffin was used shortly afterward in safety match splints is shown by a patent (*12*) taken out in 1865 on matches of that type, the patent specifically including the statement that "the composition sticks with paraffin, stearin, or other resinous substances such as commonly used for this purpose." One of the principal objections to the parlor match was the danger of the heads flying or scattering upon being struck. This was due to the difficulty in establishing a firm bond between the water-resistant wax coating on the splint and the aqueous match composition—a difficulty which occasionally arises in match factories today. This trouble was not experienced so much with sulfur-dipped matches, the sulfur and composition being more nearly compatible and easily bonded together. The higher dipping temperature of the sulfur bath also served to heat the splint and thus facilitate the bond. Parlor-match manufacturers gradually reduced the danger from head scattering, by heating the wooden splints sufficiently before applying the paraffin. This resulted in better penetration of the wax into the splint, and when the composition was applied to the heated wood it became more firmly attached than when applied to the cold, greasy splint.

From 1880 on, the number of sulfur-dipped splints produced became fewer and fewer and by 1900 practically all of the friction matches produced were provided with paraffined splints.

Moisture-proof Matches

The problem of protecting matches against moisture and making them serviceable in damp climates was an important one in the early days, as it appears that many of the phosphorus matches made at this time were unable to withstand dampness and humidity. John H. Stevens took out the first patent for waterproof matches, in 1839, his method consisting of an application of varnish or "gum mastic" to the dry match heads, the varnish being dissolved in turpentine or alcohol (*2*).

In 1841 Winans and Hyatt proposed an alcohol-base composition (*13*), containing glue 1, alcohol 4, shellac 3, phosphorus 1, and lead nitrate 3. The dangers involved in handling such a mixture limited its scope of use considerably, although a patent was granted to Ashard in 1843 for a waterproof composition containing phosphorus, potassium chlorate, antimony sulfide, shellac, and alcohol (*9*). Based, no doubt, upon sad experience with their previous formula, Winans and Hyatt took out a subsequent patent omitting the use of alcohol, using instead a basic solution of shellac dissolved in borax water, to which the other ingredients were added (*14*). The inventors "advised against the use of spiritous solutions because of their inflammability, expense, and slow drying qualities."

In 1859 a combination of phosphorus, sandarac, shellac, and alcohol was suggested (*15*) as a satisfactory damp-proof match composition, the resulting matches being "invaluable to miners, seamen, and to all other persons who wish to keep or use friction matches in damp situations." A patent was granted in the same year for externally dipping match heads in molten sulfur, thereby moisture-proofing the head and applying the flame transmission agent in one operation (*16*).

In 1868 the use of rubber as a composition ingredient was suggested by Rogers (*17*), the formula consisting of saltpeter 1, pulverized orris root $^1/_2$, minium $^1/_8$, phosphorus 1, and gutta percha 1. Dipping the dried match heads into a solution of linseed oil, oleic acid, turpentine, and rosin was suggested in 1897 (*18*). Recent patents designed to waterproof friction matches include the use of nitrocellulose base composition, a cellulose acetate base composition, and external coatings of synthetic resins (*19*).

Impregnation

Prior to 1870 match splints were not impregnated to prevent afterglow of the splint, which on occasion would cause dropping particles, and fires when carelessly disposed of. An Englishman named Howse was granted an American patent for "safety matches" in 1870, which covered impregnation of both splint and match head (*20*). Among the fire-retardant chemicals listed in Howse's patent were alum, magnesium sulfate, sodium tungstate and silicate, ammonium borate, chloride, and phosphate, zinc sulfate, and salts of both alkaline and alkaline earth metals.

A patent was issued in 1882 for a match splint fireproofed at one end only (*21*). This type of match, commonly referred to as the "drunkard's match," was designed so that the splint would refuse to burn past a certain point, generally about half-way down the splint, thus protecting the user's fingers from accidental burn in case he forgot or neglected to dispose of the burning splint after having lighted his cigar. The impregnating material was generally a concentrated solution of sodium silicate or sodium tungstate, colored with a suitable dye.

Although the practice of splint impregnation did not become general until the passage of state legislation required it (from about 1910 on), the granting of the Howse patent must be considered as an important milestone in the history of the match industry, inasmuch as it is the first recorded instance of splint impregnation.

PART IV—EARLY MODIFICATIONS OF THE PHOSPHORUS MATCH

The Fuzee

Following widespread adoption of the use of phosphorus for match purposes, many interesting modifications of the match, mostly novelties, made their appearance.

In 1832 the lucifer maker, Samuel Jones, took out a patent in England for the making of "fuzees intended to burn with a slow or smoldering flame, for the purpose of lighting cigars, pipes, etc." (*22*). It is not known whether Jones was the originator of the fuzee, as many others produced the same article, but he is credited at least with having originated the name. As stated in Jones's patent, the fuzee was intended principally for lighting smokers' articles and consisted of a cardboard splint, soaked in potassium nitrate solution and tipped with a phosphorus composition of more generous proportion than that used for ordinary matches. Jones made his fuzees in comb form so that the sensitive heads would not touch each other, and one could be torn off when needed.

Fuzees or "cigar lights" were first patented in America by John Stevens in 1839 (*23*). Stevens evidently abhorred obnoxious match fumes of any kind, inasmuch as his principal purpose in taking out the patent seems to have been the elimination of them. To avoid sulfur fumes, Stevens soaked his wood splints in a solution of saltpeter or niter just as Jones did, which caused them to burn slowly and effectively under adverse conditions. Stevens added a perfume material to his composition, however, and utilized a colored dipping solution to give his product an attractive appearance.

Some makers used rolls of heavy paper, or stout splints of tinder or of wood, in place of cardboard. Others soaked their splints in a potassium chlorate solution, or in a solution containing potassium nitrate, potassium chlorate, and sugar in order to facilitate burning even in the highest wind.

Use of the fuzee continued beyond 1890, a patent (*24*) being taken out in 1892 for a fuzee with a single-dip head mounted upon a pasteboard splint, impregnated with potassium nitrate solution. The composition contained dextrin, phosphorus, red lead, lampblack, and nitric acid.

The Wax Vesta (*22*)

The vesta was patented in England in 1832 by William Newton. The original vesta (modifications of which are being used today in certain South American countries) consisted of a wax stem reinforced with several cotton threads, tipped with the regular phosphorus composition. As time went on the vesta was greatly improved in quality, much research having been done in order to raise the melting point and increase the hardness of the wax. Machines were developed which produced the reinforced wax stems in endless strings like spaghetti.

Match splints made of sealing wax appeared to a limited extent in 1841.

An early description of "candle matches," a type of vesta invented by Savaresse and Merckel in 1836, follows (*1*):

> "Candle matches are prepared with a weaving loom carrying a chain disposed for weaving. Each match wick is composed of pieces of cotton, not twisted, and represents one thread of a chain. One or two hundred of these wicks are rolled on a cylinder separated by a comb and passed through a bath of melted wax; then they are drawn into a drawing frame which renders the wax smooth, cylindrical, and adhering to the wicks. They are then cut to size by a mechanical knife, the ends removed of wax and dipped in paste, dried, and boxed. The candles are ignited by friction and give a two minute light. The (composition) paste consists of phosphorus 12, gum 14, sulphuret of antimony 3, minium (35) and nitric acid (21) 36, vermilion 1."

On certain brands of wax matches the box was provided with a small hole in the lid, which, when fitted with a vesta, acted as a candlestick and permitted full-length burning of the taper, which lasted about two minutes. Ornamental and highly lithographed boxes were furnished, often with pictures and mottoes stamped on them, some of which were funny, others vulgar.

Cigar Tips and Caps

Cigar tips were first introduced in Austria and consisted of short, pointed wood splints with heads of brightly colored composition, sometimes surrounded by a vivid rosette made of fabric, in the shape of a flower. The tip was thrust into the end of a cigar and rubbed or struck while in this position.

Cigar caps were made to insert over the end of a cigar, and consisted of brightly colored cones of paper with small knobs of composition at the tips of the cones.

Vesuvians, Flamers, or Wind Matches

Vesuvians, sometimes called "flamers" or "wind matches," were introduced in England in 1849 and like the fuzee were designed for the purpose of striking lights out of doors (*22*). They were the first of the so-called "double-dip" matches, although they in no sense resemble the present-day match of this type. The vesuvian was equipped with an extremely large pear-shaped head consisting generally of niter, powdered charcoal, and wood dust, all held together with glue. The head was tipped with regular phosphorus composition. Splints or stems were made of a number of materials, including wood, glass, and porcelain. When wood was used it was necessary to reinforce the stems by means of wire in order to hold the heads on, ignition of the latter being so vigorous and lasting that oftentimes the splint would burn through and allow the large flaming head to fall, sometimes with disastrous results.

Glass stems were made tubular in order to prevent them from cracking because of the heat from the head, and were plugged at the bottom to prevent the flame from descending the tube and burning the hand of the user.

A "cigar-lighting cinder" patented by Reimann (*25*) in 1858 is noteworthy for three reasons: (1), it involved the first recorded application of the double-dip principle in this country; (2), it is the first recorded instance of the use of plaster of Paris in match composition; and (3), the ignitable tip contained the almost unbelievable mixture of white phosphorus, plaster, gum arabic, and gunpowder. The "bulb" consisted of pulverized charcoal, niter, and wheat flour.

A wind match formula introduced in 1869 included the application of a mixture of potassium chlorate 8, charcoal 2, dissolved rubber 5, on a glass or wire splint, a small tip of phosphorus composition providing the striking surface (*26*).

A similar composition, claimed to burn without extinction for several minutes in wind or rain, consisted of potassium chlorate 10, potassium nitrate 30, and powdered hemlock bark 38.

A cigar light formula used in 1872 contained ingredients, the burning fumes of which were designed to please even the most fastidious of nostrils. Benzoin, myrrh, cascarilla bark, powdered charcoal, potassium nitrate, oil of nutmeg, oil of cloves, and gum tragacanth constituted the formula (*27*).

A formula patented in 1876 specified the following materials for use in coating glass splints: lime, powdered charcoal, cascarilla bark, potassium chlorate, and gum arabic (*28*).

It is interesting to note that a patent for a "fuzee or blazer" was granted by the United States Patent Office as recently as 1918 (*29*).

Many of the early vesuvian or wind match boxes were highly decorated and bore such fancy names as "crystal fixed lights," "wire fixed stars," "Chinese lights," "Prussian war fusees," and "Chinese crackers." "Latchford's bone stem cigar lights which will never fall off, break, or burn the fingers in using" were introduced in England in 1867 and are indicative of the troubles sometimes experienced by smokers in providing lights for their cigars, at this early date.

Pellet Matches

Pellet matches were introduced in England in 1850 and used for about 40 years to a limited extent. They consisted of small pellets made up generally of sawdust and flour, tipped with a colored composition containing phosphorus, and were ignited with the aid of a specially designed plunger machine.

The first American patent for a match of this type was granted in 1865 to Tyler, Chandler, and Standish, and consisted of a long strip of paper or tape $^1/_4$-inch wide, saturated with stearin, and provided with successive applications of phosphorus and sulfur spaced equidistantly apart, with a section of prepared strip between each dot sufficient to make a flame for the desired length of time (*30*). The tape was wound up into a roll which was inserted in a circular metal case. The end of the tape was pushed through a slit in the rim of the case into a nosepiece provided with a toothed roller. To secure a light, the user propelled the roller with his finger until a dot of composition appeared, the latter then being ignited by a hammer-like igniter mounted on the nosepiece. A patent granted in 1868 described a waxed twine or cord coated at regular intervals with igniting composition and wound on a spool or ball (*31*). When a light was desired the string was cut off at the proper place, and the composition ignited by friction.

Miscellaneous Types

Later types of phosphorus friction matches include the block and comb varieties. *Block matches* were made out of a block of wood of regular match length split or sawn longitudinally into the desired number of matches (50 or 100), but without the cutting being carried far enough to separate the individual matches, which remained attached at one end as part of the original block. These matches were usually sulfur-dipped and then tipped with regular phosphorus composition. When a light was desired the user simple broke off a splint from the block and ignited it by striking on a suitable surface. That block matches were used in substantial volume as late as 1892 is shown by a patent taken out in June of that year for an automatic wrapping machine for packaging matches of this type (*32*). A previous packaging patent granted in 1890 describes block matches as follows (*33*):

> "Block matches are those ordinary sulfur matches which are made in splints formed by splitting or cutting blocks of wood down to a certain distance so that the splints are all held together by a web below. The splint ends of the blocks are suitably treated with match composition and then the larger blocks are subdivided into smaller blocks and are so put upon the market. It is customary to wrap with paper the upper or composition ends of the blocks to protect them."

Comb matches were made out of thin strips of wood of sufficient length and width, and cut longitudinally in such a manner as to leave a comb-like edge. These edges were dipped in both sulfur and phosphorus compositions, the individual matches being broken off as needed.

The first *pull match* was invented in 1867 by Hill (*34*). The wrapper was constructed in the shape of a small book, with inside covers lined with sandpaper. The match heads were placed inside, with the composition protected by paper folds, the splint ends protruding from the wrapper, the book being held together by an elastic band. To obtain a light, a splint was pulled out while the folder was compressed between the fingers. Later types of pull matches (some of which are in use today) are of the safety type, with chlorate head and red phosphorus friction compound.

LITERATURE CITED

(1) DUSSANCE, "A practical treatise on the fabrication of matches, guncotton, colored fire, and fulminating powders," Baird, Philadelphia, **1864.**
(2) STEVENS, U. S. Patent 1413 (Nov. 16, 1839).
(3) SMITH, *ibid.*, 3773 (Oct. 3, 1844).
(4) BLAISDELL, *ibid.*, 2494 (Mar. 18, 1842).

(5) SMITH, *ibid.*, 65,838 (June 18, 1867).
(6) BONHACK, *ibid.*, 230,226 (July 20, 1880).
(7) *Oil, Paint, and Drug Reporter* (Aug. 19, 1874).
(8) *Popular Science Monthly*, **11**, 413 (1877).
(9) ASHARD, U. S. Patent 3146 (June 24, 1843).
(10) ENDEMANN, *ibid.*, 275,617 (Apr. 10, 1883).
(11) SMITH, *ibid.*, 34,649 (Mar. 11, 1862).
(12) CRANE, *ibid.*, 49,729 (Sept. 5, 1865).
(13) WINANS AND HYATT, *ibid.*, 2402 (Dec. 23, 1842).
(14) *Ibid.*, 2403 (Dec. 23, 1842).
(15) PALLEN, *ibid.*, 22,538 (Jan. 11, 1859).
(16) U. S. Patent 22,465 (Apr. 5, 1859).
(17) ROGERS, U. S. Patent 83,412 (Oct. 27, 1868).
(18) *Ibid.*, 594,133 (Nov. 23, 1897).
(19) U. S. Patents 1,875,892; 1,942,866; 2,004,436 (1930, 1934, 1935).
(20) HOWSE, *ibid.*, 123,905 (Sept. 27, 1870).
(21) PITT, *ibid.*, 256,920 (Apr. 25, 1882).
(22) *Catalogue of Exhibits*, Bryant and May Museum, London (1926).
(23) STEVENS, U. S. Patent 1414 (Nov. 16, 1839).
(24) KLEIN, *ibid.*, 485,103 (Oct. 25, 1892).
(25) REIMANN, *ibid.*, 19,719 (Mar. 23, 1858).
(26) ROGERS, *ibid.*, 95,730 (Oct. 12, 1869).
(27) HOWE, *ibid.*, 128,628 (July 2, 1872).
(28) LITTLEFIELD, *ibid.*, 177,134 (May 9, 1876).
(29) ARONSEN, *ibid.*, 1,287,819 (Dec. 17, 1918).
(30) TYLER, *ibid.*, 50,860 (Nov. 7, 1865).
(31) WOODSIDE, *ibid.*, 73,275 (Jan. 14, 1868).
(32) U. S. Patent 477,362 (July 21, 1892).
(33) *Ibid.*, 419,851 (Jan. 20, 1890).
(34) HILL, *ibid.*, 67,052 (July 23, 1867).

FREDERICK GEORGE DONNAN

(Frontispiece)

NO BRITISH chemist is better known than F. G. Donnan, who for many years served as Foreign Editor (for England) of the JOURNAL OF CHEMICAL EDUCATION. He was born at Colombo, Ceylon, on September 6, 1870, of Irish parentage. His chemical training was obtained at Belfast (B.A., 1892; M.A., 1894); Leipzig (under J. Wislicenus, 1893–94; under W. Ostwald 1894–96; Ph.D., 1896); Berlin (under J. H. van't Hoff, 1896–97); University College, London (under W. Ramsay, 1898–1900).

Brought to chemical maturity by association with these luminaries, Dr. Donnan was now ready to enter on his life work as teacher, investigator, and writer. After two years (1901–03) as Assistant Professor at University College, London, and one year as Lecturer in Organic Chemistry at Dublin, he was called to Liverpool in 1904, where he had a real opportunity to display his talents in his favorite field. He held the first special professorship in physical chemistry and designed and directed the first special laboratory for this branch at a British university (the Muspratt Laboratory of Physical and Electrochemistry). When Sir William Ramsay retired in 1913, Professor Donnan was appointed his successor in the chair of Physical and Inorganic Chemistry at University College, London. In 1928 he was made Director of the Chemical Department. He held these posts until his retirement in 1937.

In addition to his academic duties, Dr. Donnan found time to fill important extra-scholastic offices, such as President of the Chemical Section of the British Association for the Advancement of Science (1923), President of the Faraday Society (1924–26), President of the Chemical Society (1937–39), Research Council, Imperial Chemical Industries (1927–39), President of the British Association of Chemists (1941).

The main lines of research pursued in his laboratories have been: chemical thermodynamics, theory of solutions, electrochemistry, surface phenomena, colloids, emulsions, osmotic and membrane equilibria, chemical equilibria, chemical kinetics, and heterogeneous equilibria. He has also written on the scientific philosophy of biology. Dr. Donnan has edited: Reports of the Colloid Committee of the British Association; the textbooks of physical chemistry published by Longmans, Green and Co., Inc.; Mayow's chemical writings for Ostwald's "Klassiker"; the volumes on the "Colloid State" for *Actualités Scientifiques et Industrielles*. In 1928 he was invited to edit (with Hass of Vienna) the thermodynamical papers for "The Commentary on the Scientific Writings of J. Willard Gibbs." He wrote the article "Kupfer" in Abegg's "Handbuch der anorganischen Chemie," the "Programme of Research for the Chilean Nitrate Industry," etc.

Honors have come to him in well-deserved measure: C.B.E. (1920), F.R.S. (1911); Davy Medal of the Royal Society, Longstaff Medal of the Chemical Society. His honorary degrees include LL.D. from St. Andrews and Johns Hopkins, D.Sc. from Liverpool, Belfast, Durham, Athens, Coimbra, Oberlin, Princeton. Almost a score of the leading scientific societies in Great Britain, Germany, Holland, Rumania, France, India, and Sweden have been proud to confer honorary membership on him.

Professor Donnan has been invited to attend important scientific occasions in the United States and the addresses he delivered at the Dedication of the laboratories at Princeton (1929) and Yale (1923), Centenary Celebration of Franklin Institute (1924), and Commemoration Celebration at Oberlin (1929), form valuable contributions to the literature. He was elected an honorary member of the American Chemical Society in 1926.

Professor Donnan devoted many years of valiant effort to the cause of international friendship. Together with Professors Cohen and van Romburgh, he promoted the *first* international reunion of chemists after the World War (Utrecht, 1922). Since 1933 he has worked continuously to secure positions for refugee scientists, and at one time had eleven scientific exiles working in his laboratory.

At University College, he built up one of the largest schools of chemical research in the British Empire, and during the postwar years, the number of workers exceeded 70 (exclusive of the staff). His research students now hold more than thirty university professorships in England, Canada, South Africa, Australia, New Zealand, Denmark, Sweden, Japan, Hungary, India, Greece, Rumania, and the United States.

No one who has ever had the privilege of meeting this accomplished chemist will ever forget his kindliness. In a letter to the writer of this sketch, Dr. Donnan stated:

"Although known to the scientific world chiefly as the author of the theory of membrane equilibria (wherein, to my inexpressible delight and honour, my name has been linked with the immortal one of Willard Gibbs), my greatest joy in life has always been the making and helping of young scientific men. I have always allowed them to publish in their own names, for that is the true way to encourage the young investigator."

—Contributed by Ralph E. Oesper, University of Cincinnati

What's Been Going On

(Continued from page 252.)

Wood still survives as the favored material for railroad ties despite some 2500 patents for substitutes.

The current uses for synthetic rubber in the automotive industry number about sixty.

Synthetic rubber, according to Arthur H. Bulbulian, will serve the plastic surgeon, particularly in the production of artificial ears and noses.

—ED. F. DEGERING

The Geometric Interpretation of the Method of Intercepts

H. S. VAN KLOOSTER *Rensselaer Polytechnic Institute, Troy, New York*

IT HAS long been known that the thermodynamically important extensive properties of a system, as energy (E), entropy (S), total heat content (H), free energy (F), work content (A), and volume (V) are homogeneous functions of the first degree with respect to the mol numbers of the components of the system—that is to say, if all mol numbers are made n times as great, the value of the function under discussion will be n^1 times as great as before. The French scientist Duhem, after whom the familiar Duhem equation has been named, was one of the first to point out the significance of homogeneous functions in the field of physical chemistry.

Let us consider, for instance, the free energy function F. At constant temperature and pressure F is a function of the mol numbers $n_1, n_2, n_3 \ldots$ of the various components $A, B, C \ldots$ of the system, *viz.*,

$$F = f(n_1, n_2, n_3 \ldots)$$

and according to the theorem of homogeneous functions:

$$dF = \left(\frac{\partial F}{\partial n_1}\right)_{n_2, n_3 \ldots} dn_1 + \left(\frac{\partial F}{\partial n_2}\right)_{n_1, n_3 \ldots} dn_2 + \left(\frac{\partial F}{\partial n_3}\right)_{n_1, n_2 \ldots} dn_3 + \ldots \quad (1)$$

where $\frac{\partial F}{\partial n_1} = \overline{F}_1$ represents the partial molal free energy of the first component A, *viz.*, the change in F caused by the addition of one mol of component A to a large amount of the solution, such that the amounts of all other components remain constant. Similarly we write

$$\frac{\partial F}{\partial n_2} = \overline{F}_2, \frac{\partial F}{\partial n_3} = \overline{F}_3, \text{ etc.},$$

and equation (1) becomes:

$$dF = \overline{F}_1 dn_1 + \overline{F}_2 dn_2 + \overline{F}_3 dn_3 + \ldots \quad (2)$$

On integration, for constant relative composition we have:

$$F = \overline{F}_1 n_1 + \overline{F}_2 n_2 + \overline{F}_3 n_3 + \ldots \quad (3)$$

Applying these equations to the particular case of a binary system and introducing mol fractions:

$$N_1 = \frac{n_1}{n_1 + n_2} \text{ and } N_2 = \frac{n_2}{n_1 + n_2}$$

we obtain the expressions:

$$dF = \overline{F}_1 dN_1 + \overline{F}_2 dN_2 \quad (4)$$

and

$$F = \overline{F}_1 N_1 + \overline{F}_2 N_2 \quad (5)$$

where $N_1 + N_2 = 1$. Since

$$N_1 = 1 - N_2, \; dN_1 = -dN_2$$

and we can also write for equation (4):

$$\frac{dF}{dN_1} = -\frac{dF}{dN_2} = -\overline{F}_1 + \overline{F}_2 \quad (6)$$

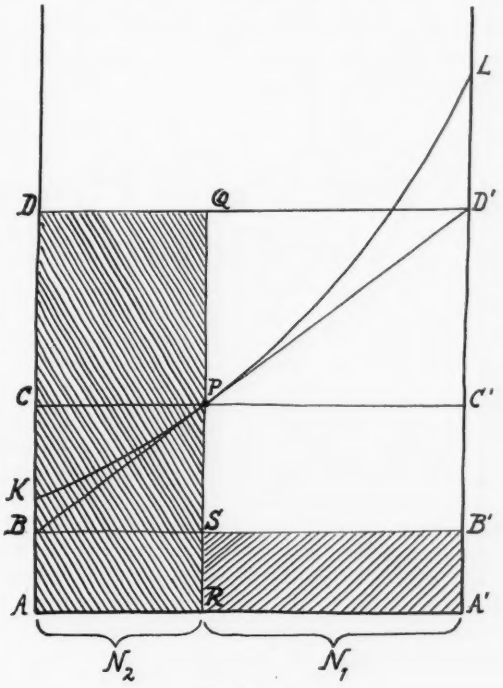


FIGURE 1

If we represent, for a binary system of *consolute* liquids, the variation in the (mean) molar free energy as a function of the mol fraction, we obtain a smooth curve which is always *convex* toward the concentration axis. Frequently this curve exhibits a minimum. For the sake of simplicity the curve in Figure 1 is drawn without a minimum.[1]

If we draw the tangent BPD' to the curve KPL in P, then according to Bakhuis Roozeboom, the intercept AB equals $\overline{F}_1$ and $A'D'$ equals $\overline{F}_2$. The proof for this so-called method of intercepts is frequently omitted in textbooks and the reader is referred to Lewis and Randall[2] for the solution. It is the purpose of this note to visualize with the aid of a few additional lines the correctness of this procedure.

[1] Since $\frac{dF}{dX}$ for $x = 0$ equals $-\infty$ and for $x = 1$ equals $+\infty$, the shape of the curve is not quite correct.

[2] LEWIS AND RANDALL, "Thermodynamics and the free energy of chemical substances," McGraw-Hill Book Co., Inc., New York City, 1923, p. 38.

In the first place, by drawing BB' parallel to AA' we note that

$$\frac{dF}{dN_1} = \frac{D'B'}{BB'}$$

or (since $BB' = AA' =$ unity)

$$= D'B' = A'D' - A'B' = -AB + A'D'$$

which fits equation (6), assuming

$$AB(= A'B') = \overline{F}_1 \text{ and } A'D' = \overline{F}_2.$$

That equation (5) is also satisfied becomes evident when we draw DD' parallel to AA' and the vertical $QPSR$ through P. The value of F is represented by $PR \times AA'$ or the area $AA'C'C$, $N_1\overline{F}_1$ equals $RA'B'S$ and $N_2\overline{F}_2$ equals $ARQD$ or:

$$AA'C'C = RA'B'S + ARQD$$

This last equation results directly from the co-linearity of B, P, and D' and can be readily verified, if we state that the rectangle $CPQD$ which lies outside $AA'C'C$ must be equal to the rectangle $SB'C'P$ which is inside $AA'C'C$. That this is the case becomes clear if we add to the first rectangle BPC and to the second BSP $(= BPC)$, and next $PD'Q$ to the first and to the second $PC'D'$ $(= PD'Q)$. We then obtain the two triangles BDD' and $BB'D'$ which are obviously equal.

Hence:

$$\overline{F}_1N_1 + \overline{F}_2N_2 = RA'B'S + ARQD = AA'C'C = F$$

The Problem of Physical Chemistry for Chemical Engineers[1]

J. C. ELGIN

Princeton University, Princeton, New Jersey

AN ADEQUATE knowledge of the fundamental principles of physical chemistry on the part of chemical engineers, always eminently desirable, is rapidly becoming a necessity as chemical engineering technics are more and more expanded and placed upon a quantitative basis. In the author's estimation there exist no minimum requirements in physical chemistry for a chemical engineer; certainly not in terms of specific topics or phases of physical chemistry. The broader and more fundamental his knowledge of this subject, if accompanied simultaneously by a real understanding of and ability to apply the principles involved, the better off he is. With the present emphasis on modern theoretical physical chemistry, the problem of providing a proper background of physical chemistry for chemical engineering students is becoming one of increasing difficulty. This brief discussion is an effort to focus the attention of chemistry and chemical engineering teachers on this problem.

It will be granted by most, I think, that physical chemistry, together with physics, forms the essential fundamental scientific basis of the unit operations and unit processes. The physical and thermal properties of fluids and solids, the principles and factors entering into the material and heat balance, the properties of solutions, phase relationships and phase equilibria, chemical reaction equilibria and reaction kinetics, the rates of interphase material transfer processes, and others are as much the province of physical chemistry as of chemical engineering. In fact much of the unit operations is simply an extension and application of the principles of physical chemistry. If the physical chemist had been interested in his subject from a different point of view—that is, the chemical engineering point of view—there might have been today no profession of chemical engineering.

Brief inspection quickly reveals that a considerable proportion of the subject matter of the average course in the unit operations and of the standard chemical engineering texts dealing with the unit operations consists in the development and application of physical chemical principles. Correspondingly, a considerable amount of time in our courses is devoted to these principles. Contributions to the modern chemical engineering and technical literature extend and utilize as their background fundamental physical chemical principles to an ever expanding extent. If the student came to his chemical engineering courses with a proper and adequate knowledge of physical chemistry, the time consumed at present in teaching him principles could be profitably devoted to amplifying, extending, and making more comprehensive and thorough his knowledge of the unit operations, unit processes, and chemical technology, which is properly the province of his chemical engineering courses. At present, it is usually necessary to teach him the principles as well as their applications .

The author does not know how far general experience will agree with his own. But he usually finds that before teaching distillation, absorption, or extraction, for example, he must first teach the elementary principles of the phase rule, phase equilibria, vapor–liquid equilibria, the basic types and diagrammatic representa-

[1] Presented before the Chemical Engineering Division at the forty-eighth annual meeting of the Society for the Promotion of Engineering Education, Berkeley, California, June 24, 1940. The author's appreciation is expressed to the Society for the Promotion of Engineering Education for permission to publish the paper.

tion of such equilibria, elementary principles of the distillation, absorption, or extraction process, the principles of diffusion, and so on. If the syntheses of ammonia and methanol are being considered, it is usually necessary to supplement an inadequate knowledge of chemical equilibria and reaction kinetics, catalysis, and the properties of gases under pressure. Why should the student not approach his chemical engineering courses with an adequate theoretical and experimental knowledge of those things, and, among others, the laws of viscosity, surface tension, heats of reaction and of solution? These are certainly physical chemistry.

The crux of the matter is that what the chemical engineer needs primarily to know about these things constitutes the so-called classical physical chemistry, as contrasted with the modern theoretical physical chemistry of quantum mechanics, atomic and molecular structure, spectroscopy, statistical mechanics, theories of solutions, and similar subjects. A majority of physical chemists are no longer interested in classical physical chemistry.

Do not misconstrue the point of view. There is no quarrel with modern theoretical physical chemistry. This is an extremely important and fruitful field. Its contributions to the scientific bases of chemical engineering can be of major significance. However, while it is excellent for the chemical engineer to know the elements of modern physical chemistry and training in this subject is excellent scientific discipline, he needs to know something else in addition. It is more important that he have a thorough and utilizable knowledge of *modernized classical physical chemistry*. It is scarcely sufficient for him to be able to calculate the rate of recombination of two hydrogen atoms from potential energy curves, if he is unable to determine the reaction order or calculate the percentage conversion to be expected under particular conditions from experimental rate data for a technically important reaction. It will be many years before a chemical engineering process can be calculated, designed, and operated from theoretical physical chemical knowledge, quantum mechanics, or the kinetic theories alone. In the meantime such processes must be developed, designed, and operated by chemical engineers.

Besides the change in emphasis, at least part of the difficulty is due to the tremendous expansion and deepening of both physical chemical and chemical engineering knowledge in the past decades. While the physical chemist has been broadening and deepening our knowledge of the physical laws in terms of the behavior of individual atoms and molecules, the chemical engineer has tremendously expanded the application of these laws to matter in mass under a variety of conditions. Courses in physical chemistry, in the limited time available, tend more and more to emphasize modern theoretical aspects at the expense of the classical physical chemistry of most importance to the chemical engineer. The chasm thus created between the student's training in theoretical physical chemistry and its application in chemical engineering continues to widen. At the same time there is an increasing need to fill it. The author's conversations with his physical chemist friends leave him with the distinct impression that it will be up to the chemical engineer to do so.

This question has been raised without at the same time having a solution to offer for it. One possibility is, of course, to have all physical chemistry taught to chemical engineering students by chemical engineers. Or we might try to persuade our departments of chemistry to give a special course in physical chemistry for chemical engineering students, covering only the desired aspects of classical physical chemistry. Neither of these does the author approve. Comparatively few chemical engineers have a sufficiently broad background to give a really adequate course in fundamental theoretical and experimental physical chemistry. Further, it is highly desirable, if not essential, that the chemical engineering student have at least his first course from the purely fundamental scientific point of view. It is not a wise policy to confine his physical chemistry only to that used immediately and directly by chemical engineers. Even though its eventual use to him may be only discipline and an understanding of the fundamental basis of the physical principles which he applies, it does not appear to be a sound policy to omit all acquaintance with modern theoretical and experimental physical chemistry from his educational equipment. Under the prevalent conditions, the author further prefers that the so-called classical physical chemistry be given him by chemical engineers rather than as a special course by a physical chemist.

A possible solution would be to follow a first course in modern physical chemistry given by the chemistry department with a second course in applied physical chemistry covering the physical chemical principles and applications which are of major importance to chemical engineers. This course would preferably be given by a chemical engineer. There are obviously curricular difficulties in this suggestion, and it immediately comes up against the time limitation barrier inherent to the chemical engineering curriculum. However, the author regards the problem raised as an increasingly serious one which must eventually be solved. The average chemical engineering student is graduated with so poor a knowledge of physical chemistry as to handicap him seriously and prevent the full realization of the potentialities in many of the lines of endeavor which he ultimately follows.

SUMMER CHANGE OF ADDRESS

BETWEEN the dates of June 15 and September 5, all correspondence for the Editorial Office of the JOURNAL should be addressed to: JOURNAL OF CHEMICAL EDUCATION, WOODS HOLE, MASSACHUSETTS.

Structural Precipitates: The Silicate Garden Type

THOMAS H. HAZLEHURST *Lehigh University, Bethlehem, Pennsylvania*

INTRODUCTION

THE term "structural precipitate" as used here denotes that class of precipitates in which the microscopic units cluster to form a more or less permanent aggregate of definite shape and some mechanical rigidity. The vast variety in form shown by structural precipitates is the result of the diverse action of several factors: (1) the phases involved, *e. g.*, solid–vapor in corrosion, liquid–liquid in precipitated cellulose, alumina, or silica, solid–liquid in silicate gardens, liquid–vapor in creeping and stalactite formation; (2) the concentrations of the reacting species; (3) the rates of the elementary processes involved; and (4) external mechanical forces such as gravity, density differences, or traction.

It is the purpose of this paper to discuss the silicate garden type of structural precipitate in the light of experiments designed to evaluate the influence of these factors.

HISTORICAL

The first reference to "mineral vegetation" is said by Quincke (*9*) to be the record of Glauber (1684) who produced an "iron tree." Since that time these intriguing growths have attracted the attention of several men (*1, 2, 5, 6, 7, 10*), largely because of their close resemblance to the forms assumed by living organisms. Except for Lüppo-Cramer (*7*) who observed growths of silver chloride, Copisarow was the first to record that structures resembling silicate gardens may be obtained with non-siliceous media.

Analogous structures produced during efflorescent creeping and corrosion have also been the subject of investigation (*3, 4, 11*).

THE FORMATION OF STRUCTURAL PRECIPITATES

It is characteristic of structural precipitates that the material first laid down largely determines the direction and extent of future growth. In silicate garden types and in corrosion the material first deposited forms a barrier between the reactants and so tends to prevent further action. If the precipitated film is firmly adherent to one phase (*e. g.*, aluminum oxide on aluminum) and if no force is exerted to rupture it, reaction actually comes to a standstill. If the film is not sufficiently coherent it may develop cracks allowing further contact between reactants, and if it is not firmly adherent to the substratum, the mobile reactant may penetrate between the precipitate and the support and a new layer of precipitate will displace the first. In this way thick layers of corrosion may be formed.

If a force acts to break the film, new precipitate may be formed wherever a crack appears, and the form of the mass of precipitate may be anything from a roughly symmetrical, cauliflower-like growth to long, slender shoots or thin, serrated sheets. Disruptive forces may arise from several causes: (1) There is always a volume change during precipitation or solution and this might be in the proper direction to cause rupture. (2) Because of thermal effects of precipitation or solution there might be local heating to cause expansion. (3) In certain cases, particularly that of the silicate garden, osmotic forces are active.

THE SILICATE GARDEN TYPE

The growth of self-supported shoots is not confined to silicate solutions but has also been observed in alkaline ferrocyanides, oxalates, chromates, arsenites, arsenates, and stannates (*1*). The present author's experiments permit phosphates, borates, zincates, aluminates, plumbites, polysulfides, and even sodium carbonate and hydroxide to be added to the list, which is surely not exhaustive. Also a great variety of crystalline matter may be used as "seed."

Because of the highly concentrated solutions used (the solution around the "seed" being saturated in the typical case) the precipitates are likely to come down at first in a gelatinous form even though normally crystalline (*12*). It would seem to be absolutely necessary that the initial precipitate be gelatinous and capable of forming a continuous film or membrane, that is, to possess a modicum of elasticity, if structural growth is to occur.

The shape assumed by the final structure and the rate of growth vary widely with the choice of material. The rate of growth clearly depends upon (1) the rate of osmosis which bursts the membrane at intervals or causes the salt solution to overflow, and hence (2) upon the concentration of the interior solution, which, in turn, can be maintained only by the solution of more salt, and so (3) upon the rate of solution of the salt. Thus, highly soluble salts with a high rate of solution should cause the growths to form most rapidly. This is borne out by experiment. Ferric chloride, the salt used by Glauber a quarter of a millenium ago, is one of the best "seeds."

Of all the media tried, water glass forms the most striking growths. This happens for two reasons. The precipitated material in this case is highly complex and is derived not from one reaction but from several. When ferric chloride is dropped into a solution of water glass, it dissolves rapidly to form a quite acid solution. Since the silicate solution is basic and since silicic acid and ferric hydroxide are both highly insoluble, the resulting precipitate probably contains not only one or

more of the possible ferric silicates, but also silica, ferric hydroxide, and basic ferric chlorides, all of which are frequently gelatinous. As was previously observed by Ross (*10*), the metallic ions may be easily leached out of these masses of precipitate by dilute hydrochloric acid, an indication of the composite nature of the precipitate or of the looseness of combination between the metallic and silicate ions.

The growths change their texture upon aging, becoming, in general, brittle and crystalline. The very existence of the growth depends upon the fact that this change is *slow*, because agglomerates of crystalline material have little mechanical strength and are so full of cracks that growth in a preferred direction would be out of the question. Mixtures of gelatinous materials would surely crystallize much more slowly than would a homogeneous gel, so that complex precipitates would form better growths. Media other than silicates, though they may be alkaline and so offer an opportunity for the precipitation of hydroxides or basic salts of the metallic ion, do not yield a precipitate of their own when acidified.

The second reason for the excellence of water glass as a growing medium is that rapid growth requires high concentrations to ensure voluminous and gelatinous precipitation, and at the same time a large difference in osmotic pressure between the growing medium and the saturated salt solution. If the medium and the salt solution are both highly concentrated, the osmotic difference may be small and consequently the driving force insufficient to ensure rapid growth. On the other hand, if the concentration of the medium is kept low to produce a large osmotic difference, the precipitation will be less copious and gelatinous.

Water glass does not have a high osmotic pressure even when quite concentrated because much of the silica present is in the form of aggregates (colloidal micelles or giant ions) so that the ionic strength is quite low.

AIR-CAPPED GROWTHS

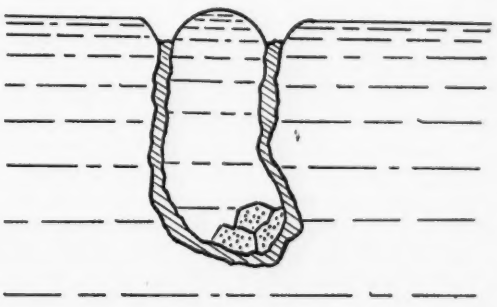
The slender shoots formed in the first stages of growth are almost invariably led by an air bubble which moves jerkily, usually first to one side, then to another, but occasionally quite irregularly and, rarely, even downward. The jerky growth of these tubes is commonly cited as evidence that a membrane bursts periodically and a new precipitate forms. However, there is no visible indication of precipitate across the mouth of the little tube inside the bubble. On the contrary, the tube seems to be filled to the brim with ordinary salt solution. It is possible to examine this phenomenon more closely by another technic.

If the salt crystal is carefully dropped upon the water glass it will not sink. Its under side at once becomes coated with precipitate and water begins to diffuse by osmosis into the little cup thus formed. As more and more water comes into the cup, the salt solution actually rises in a hemispherical contour above the rim of the cup and eventually overflows. The overflow, of course, occurs principally at one side of the cup. Immediately some fresh precipitate is formed at this point, the cup sinks to a new level, and *remains floating* once more while more water enters and a new flooding occurs.

This is strictly analogous to the rising tube led by the bubble. In this case the "bubble" is the atmosphere, and instead of the bubble rising through the growing medium leading the tube behind it, the tube sinks through the growing medium while the "bubble" remains stationary. In each case a tube is formed, which clings tenaciously to the surface. Liquid may be sucked out of it with a capillary tube and more seed crystals put in to lengthen the growth. Usually the tube is roughly cylindrical, and in that case growth will continue almost indefinitely. Sometimes the walls as they grow follow a conical surface and each successive addition to the rim is smaller than the last. Eventually the rim becomes vanishingly small and the whole growth sinks (to continue another form of growth on the bottom). This, too, has its counterpart in the growths led by bubbles because quite frequently they become smaller as they rise and at last release their bubbles.

As the crystals become completely dissolved, the solution rising to form the overflow becomes dilute and the fresh precipitate formed is a less concentrated and therefore weaker gel. Occasionally it becomes so weak as to neck off under the weight of the hanging tube, allowing the majority of the growth to fall.

Growths formed in a solution saturated with borax and boric acid seem never to be led by bubbles. This may be correlated with the fact that crystals cannot be floated on the surface of such a solution. Crystals can be floated and hanging growths produced at the surface of solutions of either sodium polysulfide or sodium plumbite.



CROSS-SECTION OF TUBE SUPPORTED AT THE SURFACE OF THE SILICATE SOLUTION

The ferric chloride crystals are lying at the bottom of the tube and the solution of ferric chloride is rising above the rim of the tube.

A cross-section through a hanging growth is shown in the figure. It is most remarkable that neither the salt solution nor the sodium silicate is able to spread over the

rim of the tube causing it to sink. The following is offered as a tentative explanation. The first bit of spreading film is very thin, not much more than a monomolecular layer. Since the freshly formed precipitate is an excellent adsorbent for all the ions present, the spreading film would be practically pure water. But pure water would have a lower surface tension than either of the solutions in question and so, to speak loosely, would be drawn back into the solution from which it might be expected to spread. In support of this view is the experimental fact that crystals of sugar, which form no precipitate with water glass, will not float on the surface because the solution spreads over them freely.

OTHER GROWTHS

The rate of growth strongly influences the final shape. Very rapid growths tend to be tubular even when not air-capped because the pressure produced is so great that rupture of the rather elastic, gelatinous membrane gives rise to a small jet of salt solution which precipitates and not infrequently bursts again at or near its tip. Liesegang (*6*) states that very thin shoots of this kind may be solid rather than hollow. The mechanism of these growths is, in fact, the mechanism usually assigned to *all* the types of growth.

Slow growths are more likely to be lumpy and roughly symmetrical. The probable reason for this is that the aging precipitate allows cracks to develop all over it so that growth is more nearly uniform.

Tubular growths not led by air bubbles will be found only when (1) growth is so rapid that the structure is complete before the membrane loses its elasticity by crystallizing, or (2) the crystallization of the membrane is so slow that even a moderately rapid growth can attain completion before cracks develop. The first case is realized by ferric chloride in water glass, the second by ferric chloride in sodium phosphate or sodium borate.

As Copisarow also noted, very beautiful and characteristic growths may form along the wall of the container. Such growths are produced whenever the saturated salt solution makes contact with the container, that is, when (1) instead of crystals, a solution is used; (2) a growing tube touches the wall, when it will sometimes "splash" and proceed along the wall; (3) the lump of salt falling through the growing medium fails to form a tough film of precipitate about it before striking the bottom, in which case it "splashes" against the bottom and spreads in all directions along the walls.

Finally, there are the tubular growths which occur late in the process, which are not led by a bubble but are open at the top, and which grow continuously, not by jerks. There is no doubt that these growths are open because proper illumination will show the "schlieren" of a column of liquid rising continuously out of them. They are formed by the following mechanism:

Water enters the capsule of precipitate around the salt crystals principally at the bottom where the concentration of the salt solution is greatest and the osmotic difference highest. The incoming water forms a layer of diluted solution along the walls of the membrane and the less dense liquid tends to rise. As long as the salt crystals continue to dissolve fast enough to maintain the solution nearly saturated in spite of the influx of water, growth will be rapid and the solution bursting through the membrane will be highly concentrated and will cause instant precipitation.

A time is eventually reached when, because the crystals dissolve too slowly to maintain near-saturation or because they have already dissolved completely and the solution becomes progressively more dilute, the incoming water flows upward along the membrane so that the escaping liquid is a very dilute salt solution. If such a liquid escapes through a crack into the silicate solution, no precipitate is produced immediately and the low density of the emerging fluid causes it to rise vertically. Since it is usually not entirely devoid of metallic ions, there is a slow, continuous deposition of precipitate at the mouth of the crack and the resulting structure is in many ways similar to the cones formed by geysers. While this sort of growth is ultimately dependent upon osmotic forces, it is not caused by alternate formation and rupture of membranes. The membrane is an open sack and no bursting is necessary. The growths are usually not very tall and are invariably vertical and straight. They are formed when (1) the crystals are not very soluble or dissolve only slowly; (2) the crystals have almost completely dissolved; (3) the precipitate formed is one which is unable to maintain the gelatinous state for any length of time and crystallizes so rapidly that only when thick layers have been built up is anything approaching semipermeability produced; (4) the portions of precipitate formed early have had time to age and develop cracks.

SUMMARY

Structural precipitates such as those formed in "silicate gardens" can be produced in many media including, in addition to those already known, alkaline phosphates, borates, zincates, aluminates, plumbites, and polysulfides. The growths are of four types: (1) tubular growths led by an air bubble or hanging from the surface of a solution, (2) lumpy or tubular growths produced by alternate formation and rupture of a somewhat elastic gelatinous membrane, (3) growths along a supporting glass surface, and (4) open tubular growths produced without bubbles at the end of the growing process.

Only type (2) growths permit of the usual explanation advanced for the "gardens." The air-capped tubes are of peculiar interest because neither the salt solution nor the growing medium under the conditions of growth will spread over the rim of the tube. A tentative explanation of this behavior is advanced.

Reasons for the surpassing excellence of water glass as a growing medium are given and general conditions governing the various types of growths are laid down.

LITERATURE CITED

(1) COPISAROW, *Kolloid-Z.*, **9**, 298 (1912).
(2) DOLLFUS, *Compt. rend.*, **143**, 1148 (1906).
(3) HAZLEHURST, *J. Phys. Chem.*, **40**, 439 (1935)
(4) HINEGARDNER, *J. Am. Chem. Soc.*, **55**, 1461 (1933).
(5) LEDUC, *Compt. rend.*, **141**, 280 (1905); **143**, 842 (1906).
(6) LIESEGANG, *Kolloid-Z.*, **9**, 298 (1912).
(7) LÜPPO-CRAMER, *ibid.*, **9**, 116 (1912).
(8) MOORE AND EVANS, *Proc. Roy. Soc.*, **B89**, 17 (1915).
(9) QUINCKE, *Ann. Phys.*, (4) **9**, 1 (1902).
(10) ROSS, *J. Proc. Roy. Soc. N. S. Wales*, **44**, 583 (1912).
(11) TAUBER AND KLEINER, *J. Am. Chem. Soc.*, **54**, 2392 (1932).
(12) VON WEIMARN, "Zur Lehre von den Zustanden der Materie," Dresden, **1914**.

Students and the Selective Service Regulations

THE latest developments in the matter of the occupational deferment of chemists and students of chemistry are shown by the following letter from the Deputy Director of the Selective Service System to all State Directors.

NATIONAL HEADQUARTERS
SELECTIVE SERVICE SYSTEM
21ST STREET AND C STREET, N.W.
WASHINGTON, D. C.

April 22, 1941

MEMORANDUM TO ALL STATE DIRECTORS (I-62)

SUBJECT: OCCUPATIONAL DEFERMENT OF STUDENTS AND OTHER NECESSARY MEN IN CERTAIN SPECIALIZED PROFESSIONAL FIELDS (III)

PART I: OFFICE OF PRODUCTION MANAGEMENT FINDINGS AND POLICY

The following letter to the Deputy Director has been received from the Associate Director of the Office of Production Management:

"From studies which I have asked the Bureau of Labor Statistics to make, I conclude that the supply of manpower in the specialized professional fields listed below, which have a definite and direct relationship to the national defense program, is at a dangerously low level. It is necessary that this level be raised by every means within our power. Certainly the flow of trained graduates into these fields should not be unnecessarily interrupted by the action of any agency of Government. It is my conclusion that the national interest requires that students be encouraged to continue their education in these fields and that the principle of occupational deferment under the Selective Service program may be used to assure their future availability to all activities relating directly or indirectly to the national defense program.

"The Bureau of Labor Statistics has been represented at various conferences in discussing this general problem and has, on its own initiative, interviewed responsible people important in the special branches of the professions, with a view to getting a cross section of opinion on the matter. It is reported that the uncertainties arising from the attitudes of local draft boards have already affected the registration of students for graduate work in the professional fields. *Therefore, it is urgently recommended that the most serious consideration be given by the Selective Service System to the individual occupational deferment of students in the following courses, so long as they continue to be in preparation or training as necessary men in activities necessary to the national defense:*

Engineering
- Civil
- Electrical
- Chemical
- Mining and Metallurgical
- Mechanical

Chemistry

"The above occupations have been especially studied by the Bureau and a *dangerously low level of manpower is found to exist therein.* Therefore, the immediate attention of Selective Service is requested to the problem preventing any unnecessary increase of these shortages so that the national defense program will not be impeded unnecessarily.

"The following are professional occupations in which authorities allege that a shortage will exist, but which have not yet been studied by the Bureau. However, there is complete agreement among representatives of industry, of American colleges and universities, and of the practicing professional groups that the present and future demands of the national defense program for college-trained scientific personnel will transcend the normal supply of graduating students that comes onto the labor market at the close of the academic year.

- Engineering
  - Agricultural
  - Sanitary
- Dentistry
- Pharmacy
- Physics
- Biology and Bacteriology
- Geology
  - Geo-Physics
  - Meteorology
  - Hydrology
  - Cartography
- Medicine

"The result of further research, as it becomes available, will be transmitted to you as a supplement to this present report."

It is directed that this release be disseminated to all local Selective Service agencies in your State as an expression of the national policy in these fields.

In applying these broad provisions there must be no deviation from the clear statutory prohibition against group deferments. The local board has full authority and responsibility, subject to appeal, for deciding whether or not a registrant is a necessary man and whether he should be selected or deferred. It must consider all the evidence submitted in connection with each individual case and must decide each case on its particular facts.

PART II: PROCEDURE ON STUDENT DEFERMENTS

Local boards should approach the immediate problem of reclassification of those students whose order numbers have been passed over because of the temporary student deferment provided for in Paragraph 345 of the Regulations and the problem of original classification of those students who are now receiving their questionnaires, with due regard to the national policy as expressed in Part I.

In order to assist local boards in applying the broad provisions of the above policy and general findings of fact to individual cases, a suggested procedure for presenting detailed facts to local boards having jurisdiction of cases of individual students has been prepared by the American Council on Education and concurred in by National Headquarters of the Selective Service System.

This procedure is set out in detail in the American Council on Education's Bulletin No. 10, sufficient copies of which are being forwarded to your headquarters under separate cover to allow for a distribution of one per local board. In brief this procedure

provides for getting into the hands of the local board a "Student Statement of Information" presenting the student's statement of his status and plans, and an "Affidavit of the College or University" in which the college officials testify as to the student's standing, courses and occupational objectives, together with a general evaluation of the student as a "necessary man." This information should be considered by the local board in the same manner as a Form 42 in other occupational deferment cases.

It is requested that State Directors coöperate with the colleges and universities in their respective States so that uniformity of operation may be attained. Similarity of procedure will be of mutual advantage.

LEWIS B. HERSHEY, *Deputy Director*

Bulletin No. 10, referred to above, was issued by the American Council on Education under the general title "Higher Education and National Defense." It was dated April 16, 1941, and is presumably on file in every college and university. It is semi-official in character, being approved by the Selective Service System. Some of its pertinent sections are the following:

The Regulations have been amended to provide that the local boards may postpone the time for induction of a registrant "in cases of unusual hardship." By way of interpreting this provision General Hershey has stated that in his opinion the induction of a registrant at the normal time may result in unusual hardship if he requires additional time to (among other things) complete a course of training or instruction, or to take an examination after completing such a course. This may apply to any student regardless of his course or year in college. Such postponement is not, however, on a blanket basis, since the local board must make its decision upon the facts of each case. It is presumed that the board will be guided by this interpretation of the Regulations.

Students may procure from their local boards a fairly accurate estimate of the date they will be called for induction. If the student's order number is such that he will probably not be called until after the summer session, semester, or college year is well along and he has enrolled in good faith, it is expected that the local board will decide that in such a case an unusual individual hardship exists and will postpone his induction until the end of the session, semester, or college year.

If, as now seems probable, those who have become 21 since last October 16 are required to register on October 16, 1941, such students will fall within the group for whom unusual hardship will exist as they will be well into the semester's work before their order numbers are determined. If registration is held during the summer, the same principle will also apply to the new registrants.

All students who have been deferred until the end of the present college year must be reclassified by July 1, 1941. To this end, any student who has already received a questionnaire from his local board and is now deferred in Class I-D should prepare *at once*, in duplicate, a "Student Statement of Information" giving complete information as to his status and plans and any contracts or other assurances with respect to engaging in necessary employment or activity upon graduation. One copy of this Student Statement of Information should be delivered to his local board without delay. The duplicate copy should be delivered to the official or officials of the university or college designated for this purpose.

Any student who has not yet received a questionnaire from his local board should, immediately upon its receipt, follow the same procedure as above and return the Statement of Information with his questionnaire.

The university or college, upon receipt of the copy of the Student Statement of Information from the student should prepare an affidavit setting forth a transcript of the student's record in the university or college and any other pertinent information concerning the student's ability, qualifications, and training. This affidavit, together with a copy of the student's Statement of Information should be transmitted without delay to the local board having jurisdiction over the registrant.

Students should be urged to continue their education until called for induction and the recommendation for occupational deferment should be made for such students for whom deferment is judged by the university to be in the best interests of national defense.

Colleges should urge individual students to appeal if, in the college's judgment and/or that of the student, a registrant is potentially a necessary man and should have been given occupational deferment or, after July 1, postponement of induction should have been granted because of unusual individual hardship. If it becomes apparent to college and university officials that a local board is disregarding or misinterpreting the letter or spirit of the regulations regarding occupational deferment or postponement of induction, it is suggested that the matter be taken up by a responsible college or university official directly with the local board or with the state director of Selective Service.

Although the Subcommittee on Military Affairs will continue to survey local board decisions and will keep an open mind on the question, it is the Subcommittee's judgment at this time that these regulations, official interpretations, and recommended procedures will achieve, through the existing Act, the twofold need: avoidance of the interruption of a student's work during the summer session, semester, or quarter in which he receives his order for induction, and assurance of a continuous supply of trained men in professions essential to the national health, safety, or interest.

A SCIENTIFIC CATECHISM OF 1870

(A list of questions to help teachers prepare examination papers)

IF FLAME is a state of combustion, is "sparking" an outlying province of matrimony?

Do people "rust out with idleness" on account of too much iron in the blood?

Do iron wheels "bite" better on a warm day for the same reason that fish do?

Are aniline and benzine members of the same family, or are they merely second cousins?

Why is the mouth of a river always larger than the head?

If tin "cries" when it is bent a little, what does it do when "struck heavy"?

Will a druggist make a good artillerist on account of his long-continued mortar practice, or a good juryman on account of his scruples, and will he maintain his business standing if he forsakes his drams?

If madder makes a lovely red, will anger make one feel blue?

Do acid people become so in consequence of the souring of the milk of human kindness?

The Alternations in Stability of Compounds of the Elements of Group V

J. H. HILDEBRAND *University of California, Berkeley, California*

THE teacher of freshman chemistry, in his search for relations illustrating the value of the Periodic System for interpolating chemical and physical behaviors, must acknowledge to his students, if he is strictly honest, that some relations are not so simple as we might like to have them in the interest of sparing mental effort. There is one such irregularity that I noticed many years ago, and which was duly recorded; namely, the alternations in stability of the oxides and chlorides[1] of the elements of Group V. This has surely not escaped the attention of others but it appears, nevertheless, never to have been discussed.

It is well known that there are no stable pentachlorides of nitrogen, arsenic, and bismuth, whereas the pentachlorides of phosphorus and antimony are quite stable. A similar difference exists for the pentoxides. Although the pentoxides of nitrogen and arsenic exist, they are stronger oxidizing agents than those of phosphorus and antimony. The elements in the neighboring groups show evidences of a similar alternation. For example, the oxides and oxyacids of chlorine and iodine are more numerous than those of fluorine and bromine. The absence of eka-iodine of course prevents the series from being so complete. Again, in Group VI, although we can hardly include oxygen in the series of oxides, the remaining dioxides show a somewhat zigzag character if their heats of formation are plotted against atomic number.

In Curve *A* of Figure 1 the heats of formation of the liquid trichlorides for the Group V elements are plotted against their atomic numbers. In the case of bismuth trichloride we know directly only the heat of formation of the solid. The heat of fusion has been estimated by assuming that the entropy of fusion would be at least as great as that for antimony trichloride. The salt-like character of bismuth trichloride would indicate that its entropy of fusion should be greater than the lower limit estimated in the above manner so that its point on the curve should be lowered, if anything. The instability of nitrogen trichloride is due mainly to the high energy of the nitrogen molecule so that it is better to eliminate the differences due to the different energies required to yield the gaseous atoms of the elements, as has been done in Curve *B*, using the values given by Bichowsky and Rossini.[2] This raises the point for nitrogen trichloride but preserves the zigzag character. Curve *C* represents similarly the heat of formation of half a mol. of each trioxide from oxygen gas and from the gaseous atom of the Group V elements.

There are, of course, a number of factors entering into the stability, but the one that appears mainly responsible for the facts noted above is the zigzag character of the higher ionizing potentials of the gaseous atoms.

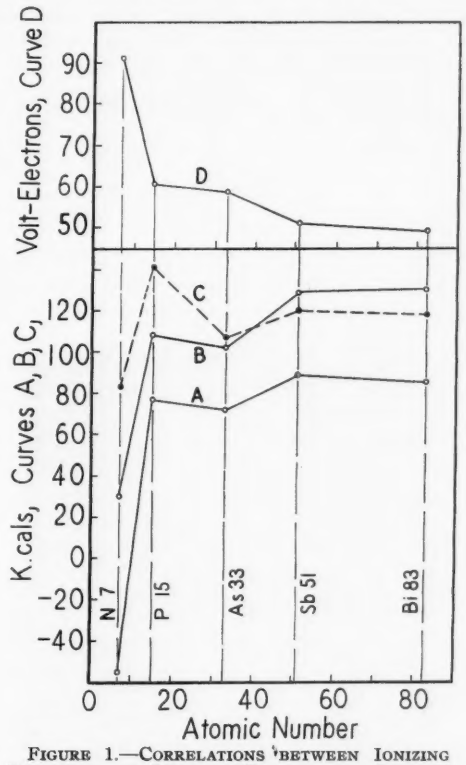


FIGURE 1.—CORRELATIONS BETWEEN IONIZING POTENTIAL AND COMPOUND STABILITY FOR GROUP V ELEMENTS

Curve *A*, heats of formation of liquid trichlorides from elements; curve *B*, same, from elements in state of monatomic gases; curve *C*, like *B*, but for one-half mol. of trioxides; curve *D*, energy for removing three electrons from atom.

The figures for these are more complete for the Group V elements than for those in Groups VI or VII. Table 1 gives the values for the first three ionization potentials,

TABLE 1

IONIZING POTENTIALS—ELECTRON-VOLTS

	N	*P*	*As*	*Sb*	*Bi*
1	14.47	11.0	10.5	8.35	7.25
2	29.46	19.7	20.1	(18.0)	16.6
3	47.3	30.0	28.1	24.7	25.4
Sum	91.2	60.7	58.7	51.1	49.3

[1] LATIMER AND HILDEBRAND, "Reference book of inorganic chemistry," The Macmillan Company, New York City, 1929, p. 167, and 1940, p. 209.

[2] BICHOWSKY AND ROSSINI, "Thermochemistry of chemical substances," Reinhold Publishing Corporation, New York City, 1936.

taken from the tabulation by Rice.[3] Their sum represents the energy of forming the tri-positive gaseous ion. These are plotted against atomic number in Figure 1, Curve *D*. The zigzag character of the line is evident. If the potentials of the fourth and fifth electrons are included, a similar zigzag is obtained.

The broken character of Curve *D* is of course related to the fact that the underlying electrons are more radically changed in the first and third steps than in the other two. The magnitude of the alternation from anything like a smooth curve is more than adequate to account for the alternations in the heats of formation. Any attempt to treat the matter in more quantitative fashion would have to take into account several other factors, not yet easy to evaluate quantitatively, such as the lattice energies of the solids and the changing proportions of ionic to covalent bond character. It seems reasonable, however, to assume that alternations in ionizing potential would be reflected in alternations in the strength of covalent bonds parallel to those for ionic bonds.

[3] RICE, "Electronic structure and chemical binding," McGraw-Hill Book Co., Inc., New York City, 1940, pp. 998–9.

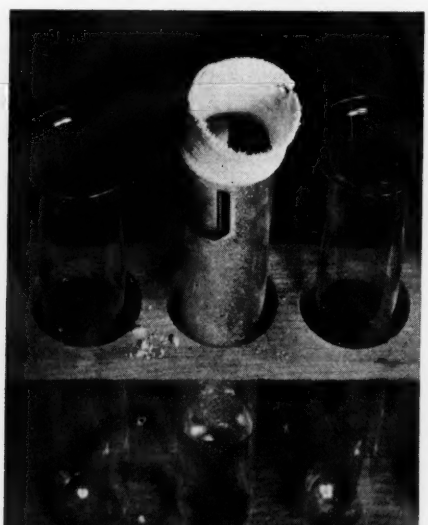
AN AMMONIUM CHLORIDE "CHIMNEY"

HARRY L. DAVIS and J. W. NECKERS

Southern Illinois State Teachers College, Carbondale, Illinois

THE accompanying photographs picture a very unusual manifestation of a very common occurrence in a chemical laboratory: the formation of ammonium chloride by the union of gaseous ammonia and hydrogen chloride. Chemical apparatus, particularly in laboratories for general and analytical chemistry, is very often coated with ammonium chloride and it is the subject of numerous questions from beginning students. Never have we known it to take this form.

This particular case occurred in a course in qualitative analysis. An ammoniacal solution of Group IV cations was left overnight in a laboratory locker to insure complete precipitation. Nearby, in a rack, was a test tube half full of a solution containing considerable excess of hydrochloric acid. The next day the beautiful formation which is pictured resulted.



Photographs by Bill Horrell

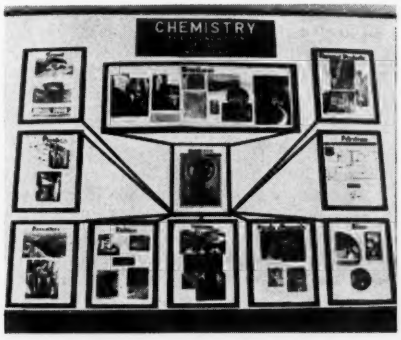
Apparently the ammonia concentration around the test tube was sufficient so that as the hydrogen chloride reached the top of the tube it immediately formed ammonium chloride, which was deposited on the lip. This reaction and deposition continued in the quiet atmosphere of the locker, with a very narrow zone of diffusion, until the illustrated "chimney" of very fragile salt was built up in successive rings to a height of nearly eighteen millimeters.

Project Teaching in High-School Chemistry

I. Exhibits and Posters

WILLIAM C. CURTIS *Dunbar High School, Washington, D. C.*

THE teaching of high-school chemistry may be greatly enriched and the offerings in the subject made more practicable through the appropriate use of project teaching (*1*). Suitable projects for use in this connection may be of a construction, problematic



A Bulletin Board Poster

or intellectual, or socialized type. Projects of the construction type may consist of an exhibit or poster illustrating the chemical principles underlying some major industry or topic of general interest, or a piece of apparatus or model for demonstrating some important principle, process, or concept. A project involving the determination of the acceptability of toilet and shaving soaps on a basis of the amount of free alkali they contain is an example of the problematic or intellectual type. The socialized type of project is exemplified by a survey to determine what false and misleading claims are made by the leading manufacturers of food products, drugs, cosmetics, cleaning preparations, etc., in their advertising campaigns.

Space will not permit a complete discussion of all of the general classifications of projects. In this article the author will attempt to present concrete suggestions for suitable posters and exhibits which may be undertaken by high-school chemistry students and from which the entire class may profit.

In the preparation of exhibits and posters, the students should be urged to design displays that involve the scientific method of thinking rather than the mere presentation of illustrative material. The students should also be required to conform with the generally accepted rules of art. In this connection, it is advantageous to have the pupils first mount their displays on ordinary paper or cardboard and submit them for approval. Profitable suggestions can then be made regarding the arrangement of material, margins, lettering, drawings, elimination of unnecessary words or explanations, etc. (*3*).

A descriptive list of suggestions for appropriate exhibits and posters is given below. Wherever possible, the sources are indicated from which material suitable for use in preparing these displays may be obtained. Sources of material for use in connection with the suggestions marked with an asterisk may be found in the articles by Bell and Hansen (*5*).

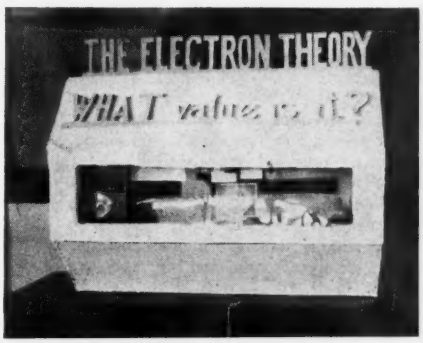
SUGGESTIONS FOR EXHIBITS AND POSTERS

History of Chemistry

Chemical Elements and Their Discoverers
Chemistry's Hall of Fame
Dreams Come True—How the modern chemist has fulfilled the dreams of the alchemists by surpassing nature in the preparation of dyes, producing artificial and induced radioactivity, and bringing about the transmutation of elements.
The Evolution of the Modern Chemistry Laboratory
How Chemical Products Are Invented—The procedures usually involved in the invention of a new chemical product to take the place of an old and faulty substance.

General Chemistry

Colloids in Daily Life*
Composition of the Human Body



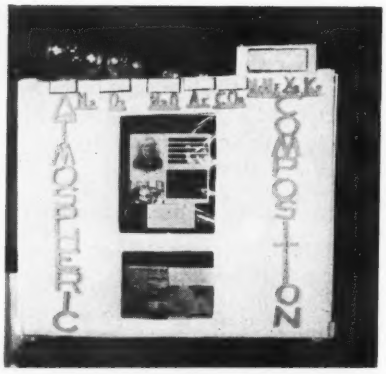
A Revolving Drum Exhibit

Electron Theory—How the electron theory explains:

(*a*) Dalton's Atomic Theory.
(*b*) The different proportions in which elements combine to form compounds (valence).
(*c*) The periodic behavior of elements.
(*d*) The existence of metal and non-metals.
(*e*) The behavior of noble gases.
(*f*) Radioactivity.

(*g*) The characteristic spectra of elements.
(*h*) The photoelectric effect.
(*i*) The existence of isotopes.

General Behavior of Gases
Liquefaction of Gases and Cooling by Expansion*—Copeland Co., 639 Lycaste Avenue, Detroit, Michigan; Servel, Inc., Evansville, Indiana
Matter Undergoing Change
Metric System—The history and use of the metric system, its important advantages over the English system of weights and measures, and the difficulties we would encounter in adapting it to everyday commercial relations. Metric Association, 156 Fifth Avenue, New York City
Principles of Separation—How mixtures are separated into their components in the laboratory and in industry.
The Use of Chemical Terms in Modern Advertising



A SEMIDIORAMA

CHEMISTRY AND INDUSTRIAL AND ECONOMIC PROGRESS

Important Industrial Products

Abrasives—Behr-Manning, Educational Service Department, Troy, New York
Alkalies—Michigan Alkali Company, Wyandotte, Michigan; Solvay Process Company, Syracuse, New York
Alloys*—A chart showing the composition and uses of the more common alloys such as bronze, brass, Wood's metal, pewter, solder, German silver, dental alloy, nichrome, sterling silver, stainless steel, etc.
Coal Tar*—A chart or panel showing the approximate amounts of coke, coal tar, fuel gas, ammoniacal liquor, and coal tar produced by the destructive distillation of one ton of soft coal, together with pictures or models of the apparatus and equipment employed for this purpose.
Coal Tar Products*—A chart or panel showing some of the important coal tar derivatives and their use in the production of dyes, perfumes, photographic chemicals, lacquers, food preservatives, solvents, plastics, etc.
Dyestuffs and Their Application to Textiles, Paper, and Other Materials
Explosives*
Glass*—L. J. Houze Convex Glass Co., Point Marion, Pennsylvania; (Colored glass) Owens Corning Fiberglass Corp., Toledo, Ohio
Important Metals and Non-Metals*
Leather—Ohio Leather Co., Girard, Ohio; Tanners' Council of America, 100 Gold Street, New York City
Linoleum*
Paints, Pigments, Varnishes, etc.*—The Chemical and Pigment Co., St. Helens, Baltimore, Maryland
Paper and Cellulose Products—Hammermill Paper Co., Erie, Pennsylvania; Strathmore Paper Co., West Springfield, Massachusetts
Petroleum*
Plastics—Celluloid Corporation, 10 East 40th Street, New York City; E. I. du Pont de Nemours and Co., Plastics Division, Wilmington, Delaware, (Plastacele, Lucite) Special Plastics Division, Arlington, New Jersey; Keasbey and Mattison Co., Ambler, Pennsylvania; Monsanto Chemical Co., Plastics Division, Springfield, Massachusetts; Polaroid Corp., 285 Columbus Avenue, Boston, Massachusetts; Westinghouse Micarta Works, East Pittsburgh, Pennsylvania
Rubber—The Sap that Made Good*—The B. F. Goodrich Rubber Co., Akron, Ohio; The Ruberoid Co., 500 Fifth Avenue, New York City
Soap*
Textiles or Clothed by Chemistry—Agriculture Extension Service, University of Arizona, Tucson, Arizona; American Viscose Corp., Educational Department, New York City; Associated Wool Industries, 386 Fourth Avenue, New York City; The Corticelli Silk Mills, Florence, Massachusetts; Botany Worsted Mills, 1450 Broadway, New York City; Forstman Woolen Co., Passaic, New Jersey; Jacques Wolf and Co., Passaic, New Jersey; Klearflax Linen Looms, Inc., Duluth, Minnesota; S. Stroock and Co. Inc., 404 Fifth Avenue, New York City; Textile Education Bureau, 401 Broadway, New York City; Warren Featherbone Co., Three Oaks, Michigan

Basic Industries and Resources

Advance of the Nation through Chemistry—How chemistry serves as the open sesame and conservator of our national resources, and prevents our complete dependence on foreign supplies.
Chemistry in Relation to Agriculture—National Fertilizer Association, Washington, D. C.; The Chemical Foundation, Inc., 654 Madison Avenue, New York City
Chemistry Eliminates Waste
Chemistry in Relation to Fire Fighting*
Electrochemistry and Industry*—The Electric Storage Battery Co., Allegheny Avenue and 19th Street, Philadelphia, Pennsylvania

Chemistry and Hygienic Progress

Chemical Tests to Aid Diagnosis—The importance, methods of administering, and limitations of the most widely used clinical tests.
Chemistry in the Prevention of Disease through Destruction—The importance of fumigation, sterilization, disinfection, and the use of insecticides and fungicides in the prevention of disease. McCormick and Co., Inc., Baltimore, Maryland
Chemistry in the Treatment of Disease—The importance of anesthetics, antiseptics, X-rays, serum therapy, chemotherapy, glandular therapy, electrotherapy, specifics, and synthetic products.
Chemistry in Relation to Cleanliness and Sanitation in the Home
Chemistry in Relation to Community Sanitation
Chemistry in Relation to First Aid and Household Safety
The Patent Medicine Trade—The composition of common nostrums, advertisements from current publications, accompanied by explanations of fake remedies, false and misleading claims, reported analyses, and samples of popular proprietary medicines.
Harmful Ingredients in Foods, Drugs, and Cosmetics
Chemistry of Foods and Digestion
Chemistry of Fats, Oils, and Waxes
Chemistry of Carbohydrates
Chemistry of Proteins
Chemistry of Vitamins and Mineral Nutrients
Chemistry of Milk—Evaporated Milk Association, 231 South LaSalle Street, Chicago, Illinois; National Dairy Council, 111 North Canal Street, Chicago, Illinois
Leavening Agents or Carbon Dioxide Raises Bread—Calumet Baking Powder Co., 4100 Fillmore Street, Chicago, Illinois;

Royal Baking Powder Co., 100 East 42nd Street, New York City

Chemistry and Social and Esthetic Progress

Chemistry as an Aid to Cultural Enjoyment—How chemistry aids in providing for a worthy use of leisure.

Chemistry in Relation to National Defense

Chemistry in the Prevention, Detection, and Prosecution of Crime

Chemistry Keeps the Woman Well Groomed—(A similar exhibit may also be constructed showing the role of chemistry in keeping the man well groomed). Bristol-Myers Co., 45 Rockefeller Plaza, New York City

Chemistry Means Comfort and Convenience in the Home

Cosmetics—A display comparing cosmetics prepared in the laboratory with similar commercial brands as to cost of production, selling price, and composition.

Fuels and Household Heating—An exhibit explaining the relative cost and heat value of fuels for heating purposes, the relative value, heating efficiency, and most appropriate uses of the chief types of heating apparatus; the value of appropriate insulation, how to calculate the actual cost of fuel for heating purposes; and how to adjust a gas burner so as to get the maximum heat or light. Anthracite Industries Laboratory, Primos, Pennsylvania; American Gas Association, 420 Lexington Avenue, New York City; Peoples Gas Light and Coke Co., Chicago, Illinois; General Insulation and Manufacturing Co., Alexandria, Indiana

CLASSIFIED BIBLIOGRAPHY

Project Teaching

(1) HAUB, "Student research in high-school chemistry," J. CHEM. EDUC., **4,** 241 (1927); LAW, "High-school projects in chemistry," *ibid.*, **6,** 1139 (1929); CURTIS, "Making high-school chemistry practical," *School Sci. Math.*, **39,** 234 (1939).

Museum Exhibits

(2) SPIERS, "A chemical museum exhibit," J. CHEM. EDUC., **6,** 130 (1929); BACON, "Displaying chemistry exhibits," *ibid.*, **15,** 219 (1938).

Posters and Exhibits

(3) STONE, "Posters in high-school chemistry," *ibid.*, **6,** 1535 (1929); RADEMACHER, "Making posters for chemistry," *ibid.*, **8,** 688 (1931).

(4) CONDON, "Chemistry exhibits in small laboratories," *ibid.*, **7,** 1649 (1930); BAKER AND PARES, "A chemistry exhibit," *ibid.*, **9,** 501 (1932); DARDEN, "Our chemistry exhibit," *Sci. Leaflet*, **13,** 36 (1939); "Twelfth annual science and engineering fair," *Sci. Observer*, **2,** 8, 14 (1940).

Sources of Project Material

(5) BELL, "A chemistry exhibit," J. CHEM. EDUC., **5,** 280 (1928); HANSEN, "Sources of project material," *ibid.*, **9,** 1078 (1932).

(6) CUSHMAN, "Sources of pictures," *ibid.*, **13,** 328 (1936).

Chemical History

(7) OPPE, "The uses of chemical history in the high school," *ibid.*, **13,** 412 (1936).

(8) WEEKS, "The discovery of the elements," JOURNAL OF CHEMICAL EDUCATION, Easton, Pa., **1939.**

Structure of Matter

(9) MILLIKAN, "Protons, photons, neutrons, and cosmic rays," University of Chicago Press, Chicago, **1935;** SPEAKMAN, "Modern atomic theory," Longmans, Green and Co., Inc., New York City, **1938.**

Chemistry of Important Commodities

Metals and Non-Metals

(10) STONE AND RADEMACHER, *op. cit.*

Soap

(11) VOTOW, "Will soaps become old fashioned?" *School Sci. Math.*, **28,** 393 (1938).

Textiles

(12) "Fireproofing fabrics," U. S. Department of Agriculture, Farmers' Bulletin 1786 and "Stain removal from fabrics: home methods," U. S. Department of Agriculture, Farmers' Bulletin 1474, Superintendent of Documents, Washington, D. C.

Chemistry in Industry

(13) "Chemistry at work," Building America Series, Vol. 3, No. 6, The Society for Curriculum Study, E. M. Hale, Milwaukee, Wisconsin, **1938.**

(14) MCCARTHY, "Plants in industry," *Sci. Leaflet*, **11,** 351 (1937).

Chemistry in the Household

Disinfectants and Disinfecting

(15) DORSET, "Some common disinfectants," U. S. Department of Agriculture, Farmers' Bulletin 1926, revised **1931,** Superintendent of Documents, Washington, D. C.

(16) WARD AND HITCHCOCK, "Household care and cleaning," Circular 416, **1934,** University of Illinois, College of Agriculture Experiment Station, Urbana, Illinois; "Methods and equipment for home laundering," U. S. Department of Agriculture, Farmers' Bulletin 1497, Superintendent of Documents, Washington, D. C.

(17) SMITHER, "Washing, cleaning and polishing materials," Circular of Bureau of Standards No. 383, **1930,** Superintendent of Documents, Washington, D. C.

Eradicating Pests

(18) HERRICK AND GRISWOLD, "Common insects of the household," Cornell Extension Bulletin 202, revised **1939,** New York State College of Agriculture, Cornell University, Ithaca, New York.

(19) HAYNE AND JEFFERSON, "Controlling rats and house mice," Circular Bulletin 167, Michigan State College, Agricultural Experiment Station, East Lansing, Michigan, **1939.**

Foods, Drugs, and Cosmetics

(20) MITCHEL AND COOK, "Facts, fads, and frauds in nutrition," Bulletin 342, Massachusetts Agricultural Experiment Station, Amherst, Massachusetts, **1937;** "Chemistry of foods," *Sci. Leaflet*, Chemistry Section, **12,** 322 (1938); "Care of foods in the home," U. S. Department of Agriculture, Farmers' Bulletin 1374, **1939,** Superintendent of Documents, Washington, D. C.

(21) CRAMP, "Patent medicines," Bureau of Investigation, American Medical Association, Chicago, **1938;** "Cosmetics and allied preparations," *ibid.*, **1938.**

Chemistry in Relation to National and Community Safety

(22) HESSEL, "Chemistry in warfare," Hastings House, New York City, **1940;** "The story of chemical warfare," Office, Chief of the Chemical Warfare Service, Washington, D. C., January, **1939.**

(23) LUCAS, "Forensic chemistry and scientific criminal investigation," 3rd ed., Longmans, Green and Co., Inc., New York City, **1935.**

SUPPLEMENTARY EXPERIMENTS IN HIGH-SCHOOL CHEMISTRY

THE Committee on High-School Chemistry has issued a Manual of Supplementary Experiments which represents the result of some of their efforts to modernize high-school laboratory work. It is tentative and experimental and the Committee hopes that many high-school teachers will try these experiments and report upon their success. The manual may be had, at the price of one dollar, from the chairman of the Committee, Mr. M. V. McGill, Lorain High School, Lorain, Ohio.

● Finding a lack of *explicitness* in commonly used laboratory manuals, Paul M. Reed of Walla Walla High School, Walla Walla, Washington, has his pupils read aloud from the manual before going into the laboratory. So doing, he claims, avoids unlearning mistakes, emphasizes cautions, and gives general improvement over the method of silent reading.

The entire question of practical procedures in secondary-school pupil laboratory exercises might well receive more attention. Does any form of direction sheet adapt itself more conveniently than another? What form of pupil reporting is convenient for both pupil and teacher, and at the same time pedagogically sound? How can laboratory exercises be conducted in very limited time most advantageously? What is the best method of distributing solids, solutions, apparatus, and papers in a laboratory class?

The correct answers to these and other similar questions would be especially welcomed at this time, for the "workshop" group is developing a set of experiments to supplement the regular set of high-school experiments. Comments from readers should be sent to Elbert C. Weaver, Bulkeley High School, Hartford, Connecticut.

LETTERS

Good and Bad???

To the Editor:

The "Gleanings from a Conference" in the March issue of the JOURNAL OF CHEMICAL EDUCATION are broadly significant to teachers of high-school chemistry. May I comment briefly on one of these statements, namely: "There is reported a general lack of ability to think, and an overemphasis on memory of questions and answers." Of all the teaching devices in use, the question and answer method is the most universally used. Other methods, such as the lecture, lecture demonstration, and group and individual laboratory work have their place, but even in these the question and answer technic is important. Testing programs quite generally employ this technic.

Good questions and good answers cannot be overemphasized, if the question is the "psychological basis" of all learning. In a classification of good and bad questions, from the standpoint of emphasis, I would include among the former, thought questions, and among the latter, questions of recall. For example, questions on the topic of fuels, previously assigned, such as: Define a fuel, does a fuel give energy, and name the solid, liquid, and gaseous fuels, can be overemphasized. Memory is tested. The purpose is to find out if the pupil got his lesson, and the price is approval or disapproval of the teacher. Such approval may become the goal rather than chemistry.

On the other hand, a question such as: Is electricity a fuel, provokes debate and leads to research. To answer this question a student must learn something about electricity, energy, and fuels, both solid and fluid. It is a thought question.

Would it not be profitable, particularly to us of your readers who are teaching high-school chemistry, to include in your columns a sample list of good and bad questions in chemistry from the standpoint of emphasis?

GEORGE W. FOWLER

BOARD OF EDUCATION
SYRACUSE, NEW YORK

What Is an Element?

To the Editor:

The point raised by E. C. Payne [J. CHEM. EDUC., **18**, 195 (April, 1941)], namely that the term "chemical element" needs redefinition in view of our long acquaintance with atomic disintegration, both spontaneous and "artificial," is worthy of study. However, his proposed definition of an element as a *substance of the second (or third) order of complexity* is not a definition, but rather a classification. Moreover, it refers more properly to the atom than to the element.

Perhaps a more explicit definition might be as follows: A chemical element is a pure substance to which, when it is isolated and purified, each and all of the following statements apply:

1. When subjected to electron or X-ray diffraction in the solid state, its lattice is shown to contain but one type of positively charged particle, though this particle may exist in groups relatively widely separated from other groups, and though negative particles (electrons) may also exist in the lattice.
2. When subjected to electron bombardment, it emits only a single set of the normal K and L lines characteristic of elements. If it decomposes, wholly or partially, to form one or more other substances or materials, the total resulting material emits under electron bombardment one or more new sets of K and L lines.
3. The atomic number as deduced from its K and L radiations by Moseley's law gives it a place in the periodic table that corresponds to the properties it shows in its combinations (or failure to combine) with other elements.
4. Its constituent particles have a dense positively charged nucleus, whose charge is proportional to the atomic number, and a relatively less dense, completely negative atmosphere ("shell").
5. When excited thermally it emits a characteristic line spectrum, peculiarly its own, which is independent of the past history of the sample but may vary according to the method and conditions of excitation. The spectrum may exhibit rotational or vibrational bands at low temperatures of excitation or in absorption spectra, but at temperatures so high that electronic line spectra are observed, the spectral lines cannot be analyzed as belonging to the spectra of two or more other elements, nor can the spectral terms be divided into sets each belonging to a different (other) element.
6. Each of its constituent particles is sometimes electrically neutral and sometimes electrically charged, though it may happen that one of these states is the normal condition and the other is attained only by the expenditure of considerable energy.

Since item 4 in the above is based on the ultimate structure of the atom and is therefore hypothetical rather than empirical, it may perhaps be omitted.

S. WEINER

2630 NORTH 53RD STREET
MILWAUKEE, WISCONSIN

We are reminded of the fact that some thirty years ago the British Association was urged to offer a prize of a thousand pounds to anyone who could completely and satisfactorily define an element within the comprehension of the layman. It seemed then—and still seems—that one must know what an element is in order to understand its definition.—*Ed.*

The First High-School Chemistry Laboratory?

To the Editor:

There recently came to my attention a letter in the April, 1941, issue of the JOURNAL having the caption: "A Chemical Pioneer in High-School Teaching." In this letter, Dr. Brandt V. B. Dixon is quoted as having claimed that a high-school laboratory installed by him in the Central High School of St. Louis in September, 1876, was as far as he could learn the first high-school chemical laboratory in the United States.

We desire to lay claim to a much earlier date for the establishment of a high-school chemical laboratory in this country. This was at the Central High School of Philadelphia, an institution that recently celebrated its one-hundredth anniversary, having been founded in 1838, the oldest public high school outside of New England. To support our contention, we quote from the "History of the Central High School of Philadelphia," by Franklin Spencer Edmonds, published by Lippincott in 1901.

Martin H. Boyé became professor of chemistry in 1851. "Provision was made for a laboratory which was fitted up in the basement, and illustrative apparatus was provided. From this time, therefore, chemistry assumed its proper place in the curriculum."—Page 113.

In 1862 during the incumbency of Dr. B. Howard Rand in the chair of chemistry (he had succeeded Professor Boyé in 1859), John Kingsbury, formerly Superintendent of Schools in Rhode Island, visited the Central High School of Philadelphia and reported: "We were particularly pleased with the chemical laboratory, not with the room, or with the chemicals, or apparatus, but with the unmistakable evidence that there was work done there.... We were informed that the chemicals were put into the hands of the pupils and they are taught to perform the experiments themselves."—Page 179.

Reference could also be made to the laboratory work done in chemistry during the professorship of the renowned Elihu Thomson (1870–80). However, the previous citations make it clear that chemical laboratory instruction started as early as 1851 and certainly was in full operation in 1862. We know that Dr. Dixon will be glad to accept this correction in order that the record may be entirely straight.

ROBERT W. KUNZIG

CENTRAL HIGH SCHOOL
PHILADELPHIA, PENNSYLVANIA

Paper for Platinum in Flame Tests

To the Editor:

In these days of another national emergency our available supply of platinum again becomes a cogent issue. An examination of the current texts on qualitative analysis reveals that their authors seemingly are unacquainted with the method developed by Ehringhaus (*Cent. Min.*, **1919,** 192, also *Annual Reports*, Chemical Society, Vol. XVII, 130) in which paper is substituted for platinum in flame-test technic.

My experience with this test, following the procedure described in *J. Ind. Eng. Chem.*, **12,** No. 5, 500 (May, 1920) long ago led me permanently to discard platinum for this purpose. Platinum has little, if any, advantage over paper; hence to use the former in this way seems to me to be an unnecessary waste of an important and valuable material.

Several methods have been devised for making bead tests without platinum wire. Small quartz or glass rods and lead-pencil leads serve for borax beads. Little, but very beautiful beads can be made with microcosmic salt as follows:

Strips of filter paper, approximately one cm. by 10 cm., are soaked in a hot saturated solution of the salt, dried, and the process repeated until crystals show on the surface of the paper. For the test place a drop of the test solution (Co, Ni, or Mn salt) on one end of the prepared strip and hold it in the outer edge of a Meker flame until the paper has carbonized to a depth of 5–10 mm. A hand magnifier will show a number of well formed and characteristic beads on the carbonized edge.

The surface tension of fused borax is such that it cannot be used in this method.

C. C. KIPLINGER

WEST LIBERTY STATE TEACHERS COLLEGE
WEST LIBERTY, WEST VIRGINIA

Editor's Outlook

(*Continued from page 251.*)

mocracy then the public must be educated on the function of higher education in a democratic society. It will be asked, why should not one man be treated exactly as another, in regard to military service? But when have we ever supposed one man to be like another, when one can apply higher mathematics to the study of airplane flight and meteorology and another cannot balance a checkbook? The fact that the second may make a better pilot than the former only indicates that each has a field in which he is most competent to serve. Our ideal of democracy has never involved the principle of equality of individuals, but only the equality of opportunity. Individual capacity to make use of opportunity will always differ. And if our democracy cannot capitalize such differences we might as well give up the struggle for it now, while we can still do so gracefully.

Out of the Editor's Basket

SERIOUS trouble was encountered in the last war through lack of a sufficient number of competent inspectors and control chemists. In order to overcome this during the present emergency, the U. S. Office of Education has formed the Bureau of Engineering Defense Training. This bureau has provided a number of educational centers throughout the country at which students having at least two years engineering training can be given a twelve-weeks' course of study on explosives and ammunition. Those who successfully complete the course will be given a Civil Service rating, making them eligible for duty as inspectors and control chemists in the various munitions plants.

● A quantitative experiment often included in courses in biochemistry is the analysis for glucose and sucrose by determination of the reducing power. Solutions containing both these sugars do not keep well, however, and must be made up frequently, due to the hydrolysis of the sucrose. In the effort to overcome this, W. B. Imbriani and E. F. Almy, of Ohio State University, sought for a suitable preservative, which they found in mercuric chloride in a concentration of 1:100,000. Solutions of the two sugars treated this way showed no increase in reducing power in six weeks' time, while control solutions were useless in a few days, the hydrolysis being accompanied by growth of molds.

● The opaque projection of demonstration experiments by instruments such as the Delineascope has been described several times. Therald Moeller, of the University of Illinois, sends in an account of two or three cases of suitable reactions in Petri dishes: (1) The failure of gas evolution from an iron file in dilute HNO_3 if rendered passive by previous dipping into concentrated HNO_3. Scratching the file restores activity. (2) Hydrogen is evolved from zinc when immersed in dilute H_2SO_4, but when a copper wire is immersed in contact with the zinc the hydrogen comes off from the copper surface. ("Couple action".) (3) Many color reactions can be well shown in this way.

● How often do we consult our students about their reactions to our system of teaching? R. D. Billinger, of Lehigh University, took a poll of student opinion at the end of the course in general chemistry. Students were asked to give each of the five principal elements of the course a rating, from 0 to 5, to indicate their relative importance, which, in terms of percentage of total points given, turned out to be: Class Recitations, 29.8; Lectures, 25.8; Lecture Demonstrations, 19.2; Laboratory Exercises, 19.8; Museum Displays, 5.1. There was only a slight difference between the evaluations made by seniors and those by freshmen; the former were somewhat more impressed by laboratory work and less by recitations.

● Many teachers do not realize the extent to which a bulletin board can serve as a teaching aid. E. K. Bacon, of Union College, tells of some of his own experiences in this connection. He found useful source material in newspaper clippings, in periodicals such as the *News Edition* of *Industrial and Engineering Chemistry*, the scientific news sections of *Science*, and the publications of several of the local sections of the American Chemical Society. Pictures illustrating manufacturing processes and of personalities of chemical prominence proved useful, as well as advertisements, many of which have considerable educational value. Publishers' circulars are also a possible source. Cartoons and poems can frequently be found which liven up a bulletin board exhibit. Of course, a large consideration in all this is that the material can be had at no cost and can often be used several times.

● In many states prospective high-school teachers are required to take a course in the teaching of at least one of the subjects they propose to teach. The problem of making courses in the teaching of chemistry both interesting and profitable seems not always to be an easy one. C. F. Atkins, of Johnson C. Smith University, Charlotte, North Carolina, tells how he has conducted such a course for the last eight years. The first half consists of a study of methods of teaching and strictly educational matters. Reference books are used and reading assignments from the periodical literature. His list of the latter is almost solely taken from this JOURNAL. A discussion of these references takes half the available time. As a special project each student is required to draw up a purchasing order for the necessary equipment to carry out some 35 lecture and laboratory experiments which he chooses, and to keep within a minimum price. The latter half of the course is devoted to subject matter, the students giving short lectures on various chemical subjects.

● A method of "finger printing" paper and other porous material has been developed by B. W. Nordlander of the General Electric Research Laboratories. The material is pressed against printing paper coated with selenium sulfide and exposed to mercury vapor. The vapor passes through the pores of the material and the pattern is imprinted darkly upon the paper. Each material produces a characteristic design which gives a graphic record of the porosity. There is a possible application to the making of bills, secret documents, etc.

● "Silicate P's and Q's," No. 4, 1941, recently issued by the Philadelphia Quartz Company (121 South Third Street, Philadelphia), describes some interesting lecture demonstration experiments to show uses of sodium silicate. It can be had on request.

● A catalog of publications, posters, outlines, study units, pictorial booklets, reprints of magazine articles, all touching on some defense plan or problem, can be obtained from the Information Exchange on Education and National Defense, U. S. Office of Education, Federal Security Agency, Washington, D. C.

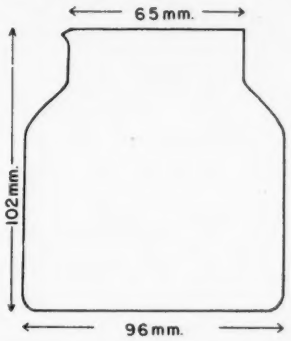
● A "Bibliography of Research Studies in Education, 1938–39" may be had (for 35 cents) from the Superintendent of Documents, Washington, D. C., as U. S. Office of Education Bulletin, 1940, No. 5. It lists more than 3500 research studies of all sorts in the field of education, including doctors' and masters' theses.

● From the United States Rubber Company comes the announcement of a new chemical and latex process known as Kolok, which is said to increase the wear resistance of fabrics, reduce their shrinking, and protect them from moths. Tests have been made upon clothing of all kinds treated by the process, which consists in depositing within the fabric minute particles of latex solids which rivet the fibers together.

● A unique medical course, designed to equip doctors and chemists to fight increased dangers of poisoning involved in the nation's defense program, will be offered during the summer quarter at the University of Chicago. It will deal not only with the usual industrial hazards but also actual combat conditions, including the use of poison gases, toxic smokes, and incendiary materials.

● The *Merck Report* for April, 1941, carries an article on "The Physician as an Expert Witness" which contains some worth-while information for chemists, as well. It can be secured from Merck and Company, Rahway, New Jersey. One never knows when he may be called into court to testify as a scientific expert.

● The accompanying sketch of a glass water bath was sent us by George Hunter, of the University of Alberta. A large number of these were made to specifications by the Corning Glass Works, whence more may presumably be had by anyone interested. Particularly designed for test tubes and "sugar tubes," they may also be used for evaporating dishes and casseroles. Advantages include visibility, low cost, easy storage.



● Although science is fast relegating old-fashioned methods of production control to the background, we understand that there has not yet been devised any instrument as sensitive as the human tongue to determine whether a food or beverage tastes right. Grocery manufacturers, brewers, meat packers, tea and coffee importers, distillers—and even soap manufacturers!—still depend on discriminating tasters, a recent survey showed, following a custom which dates back to the medieval days when every monarch had his private "fall guy" to intercept would-be assassins. It was also shown that strong geographical prejudices exist among customers, as regards their liking for particular foods, drinks, and flavors.

● Supplement No. 1 to the "March of Education," a bulletin issued by the Federal Security Agency, U. S. Office of Education, is devoted to an account of the training of women for national defense.

THIRD SUMMER CONFERENCE OF THE N.E.A.C.T.

THE third summer conference of the New England Association of Chemistry Teachers will be held at the University of Connecticut, Storrs, Connecticut, August 12–15. An attractive program, both scientific and social, has been arranged, and a number of prominent guest speakers will participate. The success of the two previous summer conferences was so complete that a large attendance is expected this year. The sessions are open to anyone, whether a member of the Association or not, and visiting chemists who may be in New England at that time are cordially invited. More complete information concerning the program, registration, room reservations, etc., can be obtained from the chairman of the conference, Mr. George B. Savage, Loomis School, Windsor, Connecticut.

The N.E.A.C.T. is one of the oldest and most energetic organizations of chemistry teachers in the country and includes a large number of associate members from all over the United States. Its *Report* has been frequently quoted in the chemical literature.

RECENT BOOKS

PHYSICAL CHEMISTRY. AN INTRODUCTION. *E. A. Moelwyn-Hughes*, D.Sc. (Liverpool), D.Phil. (Oxon.), Ph.D. (Cantab.), Demonstrator of Physical Chemistry in the University of Cambridge, Messel Research Fellow of the Royal Society. First Edition. University Press, Cambridge; The Macmillan Co., New York City, 1940. viii + 660 pp. 130 figs. 18 × 26.5 cm. $9.50.

In the introduction the author says, "I have given what is, I submit, a clear account of the basic principles of modern physical chemistry and have applied them to a number of simple problems so arranged as to form a logical introduction to the specific treatment of the most relevant of current physico-chemical themes. To embrace all these themes within a single book is impossible. Facts come first."

The first six chapters of the book are devoted to "the general principles of physical chemistry" with the chapter headings: (I) Experimental Foundations of the Kinetic Molecular Theory, (II) Mathematical Formulation of the Kinetic Molecular Theory, (III) Experimental Foundations of the Quantum Theory, (IV) Mathematical Formulation of the Quantum Theory, (V) The Chemical Elements, (VI) Chemical Thermodynamics.

This is followed with applications to: (VII) Monatomic Molecules, (VIII) Diatomic Molecules, (IX) Triatomic Molecules, (X) Chemical Equilibria in the Homogeneous Gas Phase, (XI) Chemical Kinetics in the Homogeneous Gas Phase, and (XII) Crystal Chemistry.

The author states further in his introduction, "All theorems are derived; no proof is taken for granted." This is the author's plan. The execution of this plan seems to the reviewer to be good, in general. It is a book that is intermediate in scope between the more elementary physical chemistry texts and the specialized books most useful to the theoretical chemist. Many subjects discussed in elementary texts are omitted to make room for the theory of others. The values quoted for the universal constants are not the most recent ones. Hamilton's equations are used with little more than an indication of where the proof is to be found.

Most of the material can be found more extensively treated in other books, which, however, may not be in the libraries of most chemists. The treatment of reaction kinetics is necessarily compressed but goes as far in presenting modern developments as could reasonably be expected. The printing and general form of the book is excellent.

HENRY EYRING

PRINCETON UNIVERSITY
PRINCETON, NEW JERSEY

LABORATORY OUTLINES AND NOTEBOOK FOR ORGANIC CHEMISTRY. *C. E. Boord* and *W. R. Brode*, Professors of Organic Chemistry, The Ohio State University; and *R. G. Bossert*, Assistant Professor of Chemistry, Ohio Wesleyan University. John Wiley and Sons, Inc., New York City, 1940. ix + 241 pp. 28 figs. 21 × 27 cm. $1.75.

"The lecture and laboratory work in a well-rounded course in elementary organic chemistry should be kept closely parallel or coincident," to quote from the preface of this recent organic laboratory manual. As a result there has been a noticeable increase in the number of exercises dealing with aliphatic compounds, and a corresponding decrease in the number dealing with aromatic compounds. This trend corresponds to the growing interest, particularly in the American chemical industry, in aliphatic organic chemistry. Exercises on structure and nomenclature provide for the first time individual laboratory experiments which evolve the ideas of homology and isomerism.

The manual is designed for the usual thirty-six weeks' course with two laboratory periods per week, or three periods per week for twenty-four weeks under the "quarter" plan. The manual might be successfully used in shorter courses by deleting a portion of the sixty-nine exercises. Besides the usual selection of organic preparations and test-tube reactions, this manual includes eight exercises dealing with the separation and purification of organic compounds and also the qualitative identification of elements. The last two exercises involve the identification of simple organic compounds by the usual qualitative elementary analysis, solubility behavior, and the preparation of simple derivatives.

This manual is not merely another intrusion into an already crowded field. The exercises are designed to enable the instructor to handle a large number of students with a minimum of supervisory effort, allowing a major portion of his time for oral quiz and laboratory supervision. The time required for notebook correction is reduced to a minimum by well-arranged blanks and reports that students complete and leave with the instructor at the end of each laboratory period. A spiral binding is used so that the manual lies flat on the desk. This manual not only contains a wise choice of experimental material but also enough unique items of organization to command attention and consideration, especially from any busy instructor faced with the necessity of teaching large numbers of students with a minimum of effort.

RALPH E. DUNBAR

NORTH DAKOTA AGRICULTURAL COLLEGE
FARGO, NORTH DAKOTA

ELEMENTARY QUALITATIVE ANALYSIS FOR COLLEGE STUDENTS. *J. H. Reedy*, University of Illinois. Third Edition. McGraw-Hill Book Company, Inc., New York City, 1941. x+ 156 pp. 16 figs. 15 × 21 cm. $1.50.

In the third edition of this very excellent book, the same general approach has been used as in the first two editions. The contents have been divided into four parts as follows: Part I—Preliminary laboratory work; Part II—Detection of the ions of the metals; Part III—Detection of the ions of the non-metals; Part IV—Systematic analysis. The laboratory directions have been written so that semimicro procedures can be followed. Organic reagents have been deliberately avoided. Changes in the directions for the tin group analysis and for the analysis of the alkali group are interesting and appear to represent improvement.

The author's stated purpose has been to make the book consistent with the student's ability and previous training. The book does not consider difficult combinations beyond the ability of the elementary student. It is not a reference book but a laboratory manual. Its purpose is clearly that of teaching the chemistry of the common cations and anions, not the teaching of physical chemistry. The author is to be commended for having achieved this purpose in an outstanding manner.

LYMAN J. WOOD

ST. LOUIS UNIVERSITY
ST. LOUIS, MISSOURI

A DICTIONARY OF METALS AND THEIR ALLOYS. *F. J. Camm*, Editor. Chemical Publishing Co., Inc., New York City, 1940. 245 pp. 14 × 22 cm. $3.00.

This purports to be the first alphabetically arranged DICTIONARY OF METALS AND THEIR ALLOYS yet published. It contains descriptions of the metals, their composition and characteristics, with special sections on plating, polishing, hardening, and tempering, metal spraying, rust-proofing, chemical coloring, and useful tables.

THE MERCK MANUAL OF THERAPEUTICS AND MATERIA MEDICA. Seventh Edition. Merck and Co., Inc., Rahway, New Jersey, 1940. 1436 pp. 10.5 × 17 cm. $2.00.

THE MERCK MANUAL, intended for physicians, dentists, pharmacists, chemists, nurses, and those in allied professions, contains 256 chapters, each approved by a specialist in his respective field, with a comprehensive cross reference index for aid in finding the information available.

THREE IMPORTANT NEW BOOKS

CIVIL AIR DEFENSE

By Lt. Col. A. M. PRENTISS, U. S. A. 334 pages, 6 x 9. $2.75

The author of this timely book describes the various means and methods of air attack and the effects produced by each; discusses in detail protection against high explosives, incendiaries, and the different kinds of gases; and explains how to organize means of warning of the approach of hostile aircraft. The book tells how to protect both industrial establishments and homes against air raids, and in the final chapter discusses the probable influence of civil air defense on our national life and the future development of our large cities. The book is of particular interest to engineers and technical men who must solve the many problems pertaining to shelters and other means of protection against air attack.

THEORY OF RATE PROCESSES

By SAMUEL GLASSTONE, KEITH J. LAIDLER, and HENRY EYRING, Princeton University. *International Chemical Series.* 608 pages, 6 x 9. $6.00

Representing an entirely new approach to the subject of reaction rates, this new book describes the development and application of a general theory of the kinetics of physical and chemical processes usually known as the "theory of absolute reaction rates." The authors explain the fundamental, bases, and consider homogeneous and heterogeneous gas reactions, reactions in solution, viscosity, diffusion and electrochemical phenomena, in terms of the theory.

FOOD ANALYSIS. Typical Methods and the Interpretation of Results

New fourth edition

By A. G. WOODMAN, Massachusetts Institute of Technology. *International Chemical Series.* 603 pages, 6 x 9. $4.00

As before, the author of this standard text offers a detailed discussion of the processes involved in food analysis and covers comprehensively their suitabilities and limitations. All material has been thoroughly revised, particularly the chapters on alcoholic beverages, sugar methods, dyes, etc. The chapters on general methods have been largely rewritten and some of the newer optical methods of attack have been incorporated.

Send for copies on approval

McGRAW-HILL BOOK COMPANY, Inc.

330 West 42nd Street New York, N. Y.

Have you overlooked any of these new textbooks?

EACH one has features which may make instruction easier for you next Fall. Check the list of titles below. If there are any on which you do not have full information, use the coupon at the bottom of this column:

1. *BABOR and LEHRMAN*
Introductory College Chemistry (1941)
Replaces *Elements of General Chemistry.*

2. *BABOR and LEHRMAN*
General College Chemistry (1940)
The text for students who *have* had high-school chemistry.

3. *NICHOLAS D. CHERONIS*
Organic Chemistry (1941)
A tested, new approach to a difficult subject.

4. *PERKIN and KIPPING*
Organic Chemistry (1941)
Revised, enlarged edition of a standard text.

Laboratory manuals

5. **LAB. MANUAL in INTRODUCTORY COLLEGE CHEMISTRY** (1941) Specially prepared by Babor and Lehrman for texts Nos. 1 and 2 above. Many special features aid the instructor.

6. *NECKERS, ABBOTT, VAN LENTE*
Experimental General Chemistry Special edition (1941) keyed to text No. 1 above.

7. **LAB. MANUAL IN GENERAL COLLEGE CHEMISTRY** By Babor and Lehrman (1940) for text No. 2 above.

GET THIS IMPORTANT TEXTBOOK INFORMATION FOR YOUR FILES

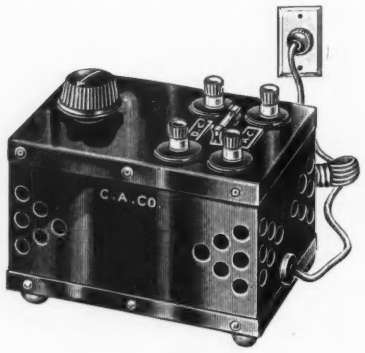
Tear out, sign and mail to
THOMAS Y. CROWELL COMPANY
432 Fourth Ave., New York, N. Y.

Send me full information about the textbooks whose numbers I have checked below.

1. 2. 3. 4. 5. 6. 7.

Name .....
Professor or Instructor at .....
Address .....

LOW-COST SUBSTITUTE FOR BATTERIES AND TRANSFORMERS



Because of its numerous distinct advantages laboratories, everywhere, are replacing batteries and transformers with this modern substation which delivers two types of low voltage current from a 60-cycle, 110 volt outlet—D.C. up to 6.6 volts, 3 amperes; A.C. up to 11 volts, 3 amperes. Either can be used separately or simultaneously and their voltage and amperage values may be smoothly and almost steplessly varied throughout their full range by the mere turn of a knob.

MANY USES: Operation of St. Louis motors, Genamotors, other motors, bells, buzzers, induction apparatus, electroplating outfits; charging storage batteries; energizing electromagnets and any other work within substation's output ranges.

MANY ADVANTAGES: Perfect portability; usable on table or wall; no chemical solutions to prepare, spill or replace; no glass bulbs to renew; no replacement or upkeep expense; no deterioration from age or idleness; always ready to deliver its full rated output of D.C. or A.C intermittently or continuously; equipped with renewable fuse which fully protects both the substation and instruments being operated.

CONSTRUCTIONAL FEATURES: Black enamel, ventilated metal case with rubber feet; convenient control knob; top plate bearing operating directions, ratings and markings for output terminals; cord with soft rubber plug; measures 4 x 4 x 6½ inches.

A.C.—D.C Substation No. 66750

$12.00

● Our catalog No. 45 lists practically every item essential to the proper maintenance of the modern chemistry laboratory. You'll save time and money by using it regularly.

Chicago Apparatus Company

Science Laboratory Equipment

1735 NORTH ASHLAND AVENUE · CHICAGO, U. S. A.

TRADE ANNOUNCEMENTS

New Electric Laboratory Furnace

The new Huppert Universal Model C Furnace has just been announced as an addition to their line of Electric Laboratory Furnaces. This model has a large muffle which measures 4½" wide, 3⅝" high and 9" deep. Its heat ranges are as follows: low, 0 to 500°F., medium 500°F. to 1000°F.; high, 1000°F. to 1800°F.

Each range is controlled by a seven-point adjustment which is said to permit accurate selection of the exact temperature desired as well as maintaining that temperature, and an easily read Pyrometer is included as standard equipment.

Exterior dimensions are: width 15", height 18", depth 20". A counter weight on the door eliminates latches and keeps the door either in the open or the closed position.

Voltage is 110 volts, either a.c. or d.c., and maximum load for high temperature is 1100 watts with minimum load drawing 220 watts. All metal parts are of stainless steel and all contacts are fully enclosed. Complete details may be had from the manufacturer, *K. H. Huppert, 1603 S. Michigan Avenue, Chicago, Ill.*

A New Oil Testing Instrument Catalog

A new 32-page catalog, No. 699E, has just been published by *C. J. Tagliabue Mfg. Co. of Brooklyn, N. Y.* It lists and describes more than 100 different types of oil testing instruments. In addition to a complete listing of A.S.T.M. thermometers and A.P.I. hydrometers, the entire TAG line of Miscellaneous and General Testing Thermometers and Hydrometers is featured.

Many new and improved petroleum testing apparatus for acid heat, gum stability, Ramsbottom carbon residue, grease consistency, kinematic viscosity, flash and fire, etc., are illustrated and described in detail.

A copy of this new catalog will be sent on request.

New Infra-Red Heat Lamps

Three new infra-red heat lamps have been placed on the market by the Birdseye Division of Wabash Appliance Corporation, Brooklyn, N. Y. Two of the lamps are clear, for use with the standard gold-plated or Alzac reflectors, but the third does not require any separate reflector since it is built with its own reflector lining sealed inside to keep it free from oxidation and the collection of dust, dirt and fumes. The manufacturer states that the reflector lining will keep heat-reflecting value for the 6000 hour life of the bulb because it is made of pure solid silver which is sealed inside the gas-filled bulb.

Complete information on Birdseye heat lamps and on the subject of baking, drying and dehydrating with infra-red radiant energy is contained in bulletin No. 121B just issued by the *Wabash Appliance Corporation, Brooklyn, N. Y.* and may be obtained upon request.

Plastic Valves Replace Aluminum in New Respirator

The miniature, Dupor No. 1 nuisance dust respirator recently announced by *H. S. Cover, South Bend, Indiana* has been made even lighter by replacing aluminum valves with molded plastic ones. The total weight of entire unit is now reduced to well under one ounce. This handy respirator designed to fit over nose only is held in place by elastic ear bands, and can be worn as conveniently as a pair of glasses. Nose piece is of soft rubber with 9 sq. in. filter pad. New plastic valve arrangement keeps stale air from backing up inside pad and also expels this air.

Industrial Chemicals

A pocket-sized booklet entitled "Industrial Chemicals" containing the names of its products alphabetically arranged has just been released by the American Cyanamid and Chemical Corporation. Also listed in this booklet are many substances for which there are special bulletins describing the product and its use in greater detail.

The above booklet and the special bulletins are available upon request to the *American Cyanamid and Chemical Corporation, 30 Rockefeller Plaza, New York.*